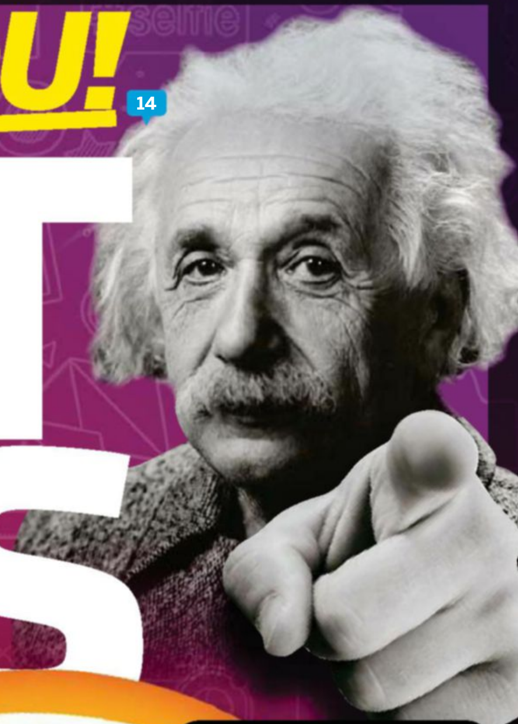
SCIENCE NEEDS YOU!

HOW TO GET INVOLVED WITH GLOBAL RESEARCH PROJECTS

14



HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT

THE SCIENCE OF SOCIAL MEDIA#

THE TECH BEHIND IT & WHAT IT DOES TO YOUR BRAIN

HOW SECURE IS YOUR DATA?

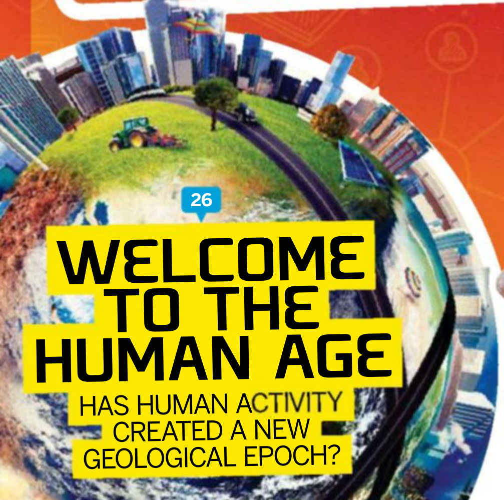
WHAT IS TARGETED ADVERTISING?

DOES SOCIAL MEDIA AFFECT YOUR HEALTH?

HOW DOES FACEBOOK MAKE MONEY?

+ CAR WASHES
JUNO AT JUPITER
AIRPORT SECURITY
THE NEW NOKIA 3310

+ FREE 2 PULL-OUT POSTERS INSIDE!



26

WELCOME TO THE HUMAN AGE

HAS HUMAN ACTIVITY CREATED A NEW GEOLOGICAL EPOCH?

34

PANGOLINS
Why these armoured animals are threatened

54

DETECTING LIFE ON EARTH
How our planet's vital signs could help us find alien life

44

SYNTHESISERS
Inside the instruments that defined 80s music

+ #IV FLUID #GAS FLARES #POMPEII CASTS

Future

ISSUE 102

Digital Edition

GreatDigitalMags.com

ISSUE 102

WELCOME

The magazine that feeds minds!

"In the next century, the global population is set to grow to between 10 and 12 billion people"

Welcome to the Human Age, page 26

Meet the team…

Charlie G
Production Editor
As you'll see on page 26, we are now living in the Human Age, or the Anthropocene to give it its unofficial title. Only time will tell if it turns out to be a period of prosperity for our planet, or its undoing.

Charlie E
Staff Writer
We had an amazing time at the Bluedot Festival at Jodrell Bank near Manchester! From displays of cutting-edge science to lectures on parasites and some great live music, find out more on page 6!

James
Research Editor
For my final issue at **How It Works**, I took a look at the clever science behind airport security, which you can find on page 64. Now it's time for me to return to the laboratory, farewell readers!

Duncan
Senior Art Editor
The advent of the atom bomb changed the world forever. We meet the minds behind the Manhattan Project on page 74 and discover how they struggled to tame the beast they created.

Laurie
Studio Designer
In a world of fake news and 'alternative' facts, how can you make sure that the science you read about is real? On page 24 we look at how to spot bad science and ensure you're getting the facts right.

FOLLOW US… How It Works magazine @HowItWorksmag

Social media has revolutionised the way we communicate and connect with each other. But does it actually make us more sociable? In our cover feature this month we answer questions on the technology behind these networks and how using them affects our brains.

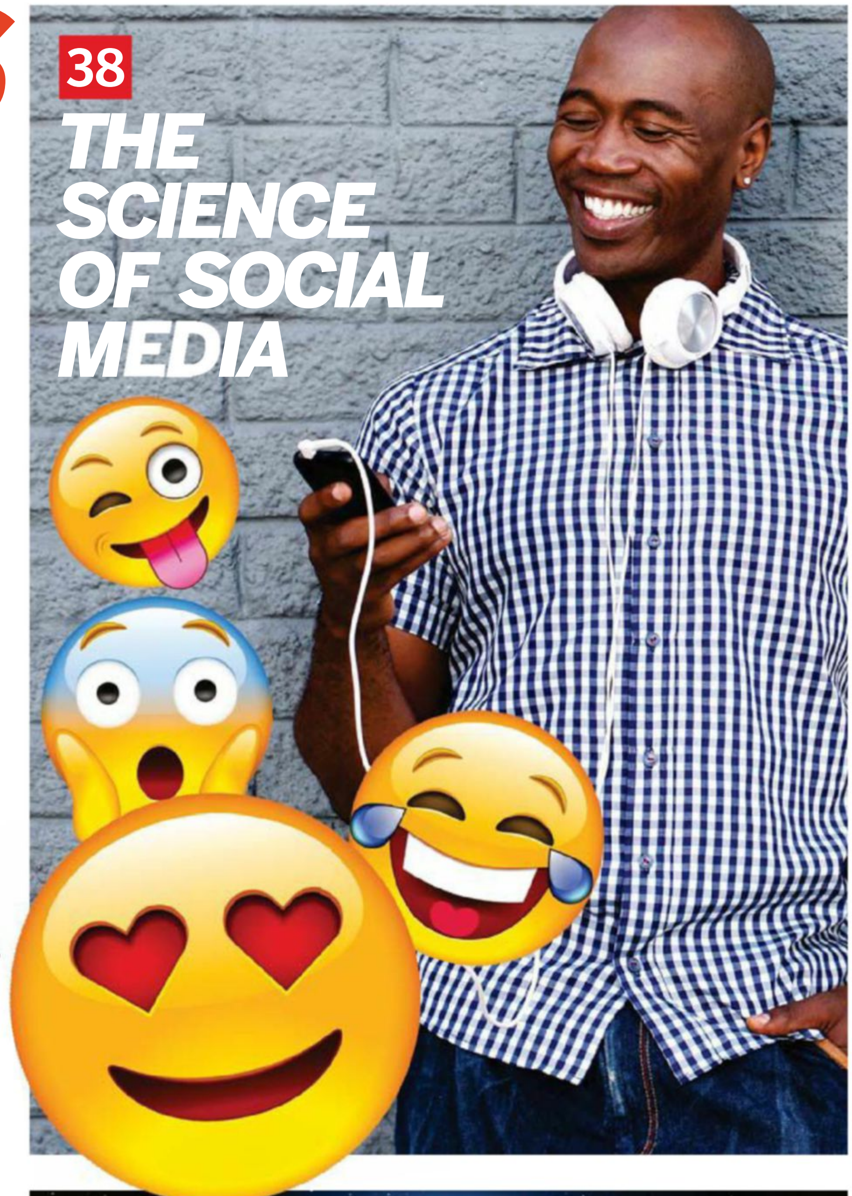
In the environment section, we investigate the case for the Anthropocene. We have clearly had a dramatic impact on our planet, but has human activity been enough to create an entirely new geological epoch? Find out on page 26.

If you've always wanted to get involved in research projects but don't have professional science experience, don't worry, there are plenty of experiments and surveys you can get involved in, either online or locally. You could help discover exoplanets, analyse genes, aid disaster relief or collect population data for vulnerable species. Check out our citizen science feature on page 14 to find out more. We hope you enjoy the issue!

Jackie **Jackie Snowden**
Editor

© Thinkstock

CONTENTS



+ FREE POSTERS
• WILDLIFE OF A IPWRECK
• THE KUIPER BELT
PAGES 49-52

Meet the experts…

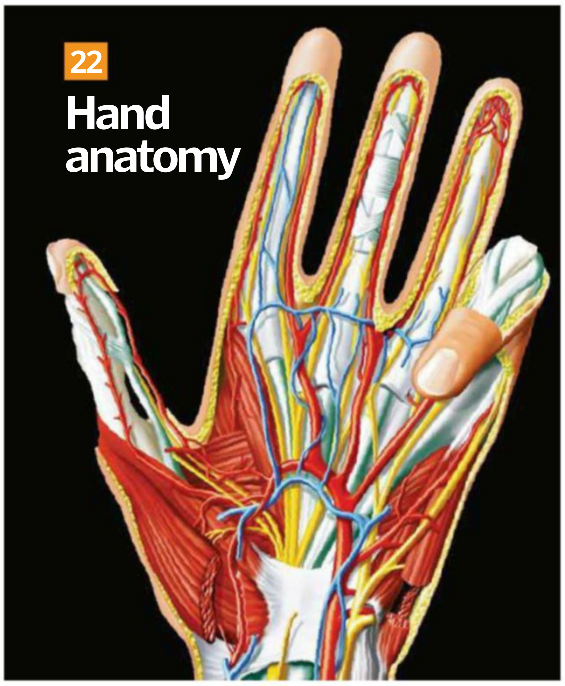
Laura Mears
This month Laura reveals the tech and psychology behind social media. Over in the history section, she explains how and why the Manhattan Project began and how its results shook the world.

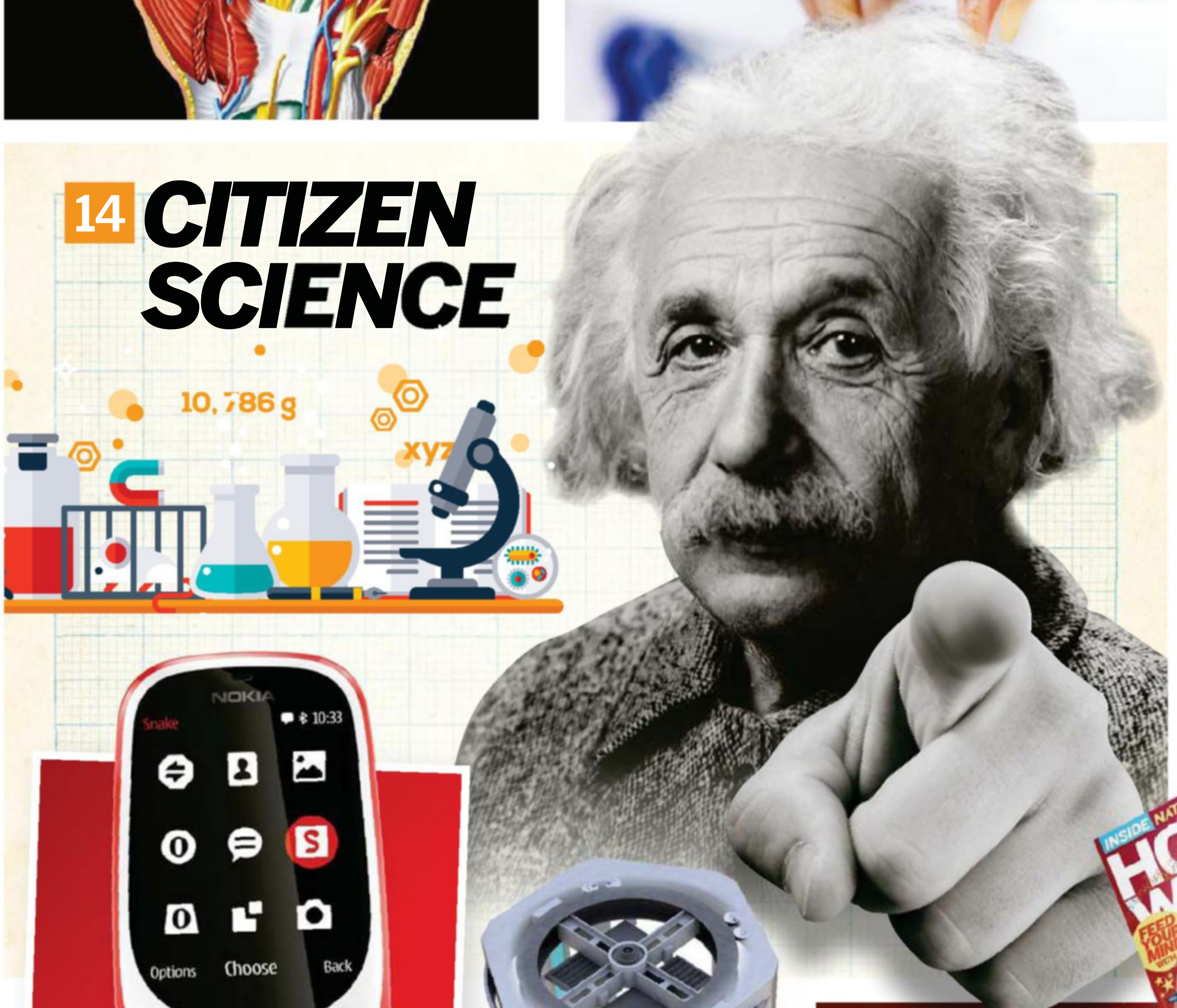
Jonny O'Callaghan
In our space feature, Jonny explains how observing Earth could help us find signs of life on other worlds. He also uncovers the tech behind synthesisers, the instruments that defined the 1980s.

Jo Stass
In the environment section, Jo examines the case for declaring a new geological epoch: the Anthropocene. Find out just how much impact we have had on our planet with some sobering stats on page 26.

Stephen Ashby
In this month's technology section, Steve compares the original Nokia 3310 to its shiny new iteration. We're hoping to see more classic phone features make a comeback – how can you pretend to be on Star Trek without flip phones?

Steve Wright
In our latest book reviews, Steve gives us his verdict on the latest releases in science and technology titles, including the Haynes Owners' Workshop Manual of astronauts from the 1960s to the present day.





10,786 g

NOKIA
Snake
10:33
Options
Choose
Back

REGULARS

SCIENCE NEEDS YOU
HOW IT WORKS
THE SCIENCE OF SOCIAL MEDIA
THE TECH BEHIND IT & WHAT IT DOES TO YOUR BRAIN

What we learned at Bluedot

How It Works visited an incredible festival celebrating a fusion of science, music and art under the iconic Lovell telescope

On 7 July 2017, the Jodrell Bank Discovery Centre became home to the Bluedot Festival for the third year running. With a line up of fantastic musicians, along with a dazzling array of scientific lectures and activities, the Bluedot Festival successfully achieved its mission to inspire and entertain.

The iconic Lovell telescope is 76.2 metres in diameter and sits within 14 hectares of spectacular gardens filled with different species of plants and over 3,000 trees. Despite reaching its 60th year in July, the telescope is still in use. The Lovell itself is steeped in history, from tracking Soviet probes aimed at the Moon in the late 1950s to holding a pivotal role in the discovery of quasars and finding evidence to support Einstein's general theory of relativity.

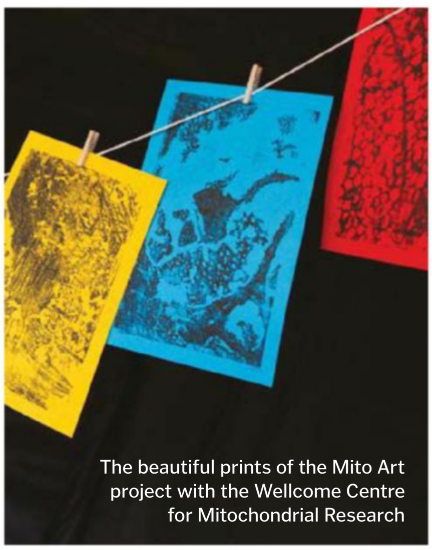
Thousands of music and science lovers gathered to celebrate over the weekend, listening to lectures on astronomy, neuroscience, animals and climate change. While the main stage hosted performances from Goldfrapp, Orbital, the Pixies (and many more), NASA scientists and university lecturers were talking about their research into finding life on other planets or tackling infectious diseases by editing genetic codes. Tents across the site brimmed with activities for all age groups, including Jedi training workshops and virtual reality gaming. We are already looking forward to next year's inspiring event!

> *"Look again at that dot. That's here. That's home. That's us."*
> Carl Sagan (1934-1996)

On you, inside you: the amazing and horrible world of parasites

Dr Sheena Cruickshank, senior lecturer at the University of Manchester, delivered an engaging lecture on the gruesome world of parasites. Dr Cruickshank explained how parasites have lived with humans for millennia and that even the famous 2,000-year-old Lindow Man was suffering from intestinal parasites. She also discussed the use of tapeworms as a treatment for Crohn's disease and talked about the increase of allergies where we see a decrease in parasitic infections. Dr Cruickshank also detailed the life cycle of the creepy, brain-controlling T gondii parasite. However, the most harrowing story was that of the victims of the jewel wasp, which turns cockroaches into zombies by stinging the bundle of nerves responsible for the cockroach wanting to escape. This creates a compliant victim who has the physical ability to escape but has lost the reflex to do so. Instead, the wasp is allowed to lay her egg on the cockroach, which later hatches and gnaws its way into the host's abdomen, devouring it from the inside.

Dr Cruickshank works to understand how infection and injury trigger immune responses

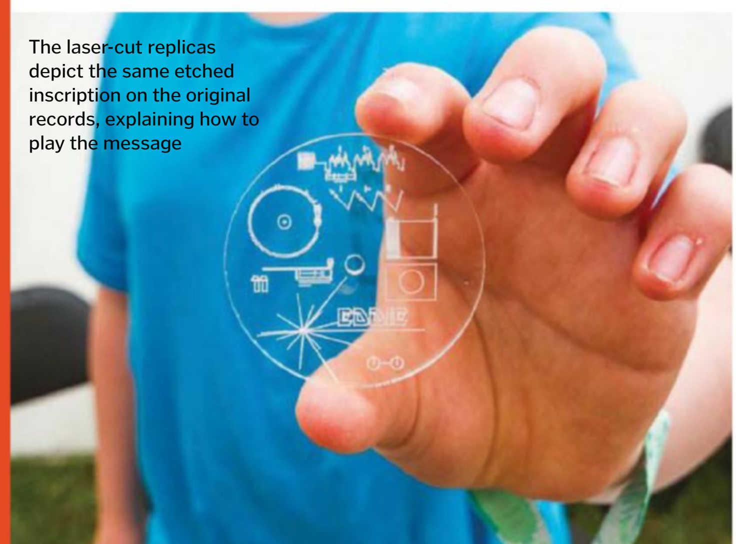


The beautiful prints of the Mito Art project with the Wellcome Centre for Mitochondrial Research

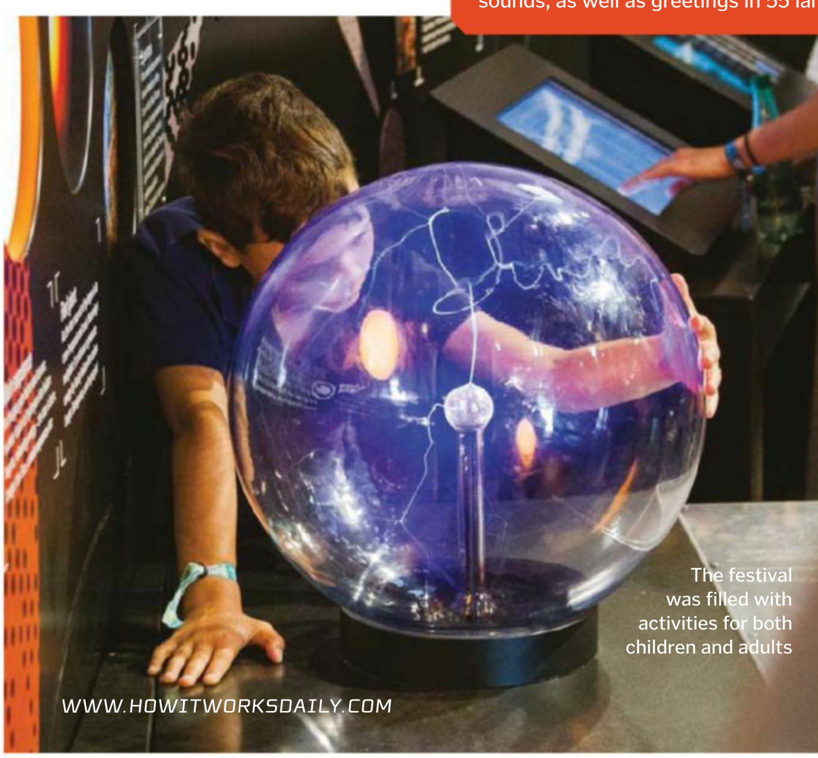
Personalising a Voyager Golden Record replica

The Making Rooms were busy during the festival engraving names on replica records of the Voyager Golden Records in a workshop space. The laser-cut replicas are based on the original metal discs that were launched into space with a communication of their origin and time etched into them. The original Voyager Golden Records were sent into space in the hopes that another civilisation may discover them in the distant future.

We spoke with the team at The Making Rooms stand, who explained the markings etched onto the replicas of the ones launched into space. The symbols on the surface include instructional binary code, which details the proper speed to turn the record. The records carry 115 images and a variety of natural Earth sounds, as well as greetings in 55 languages.



The laser-cut replicas depict the same etched inscription on the original records, explaining how to play the message



The festival was filled with activities for both children and adults

Stalls were set up from universities around the country, enabling scientists to explain their research to the public

Investigating the invisible – genetics, structure and viruses

Researchers from the Wellcome Centre for Mitochondrial Research at Newcastle University spoke about their current projects at the institution, using art as a way to engage people with the principle behind their research and demonstrate the new developments in mitochondrial treatments. The Wellcome Trust Centre for Human Genetics presented a series of interactive puzzles to demonstrate concepts such as the decoding of DNA and why genes affect susceptibility to malaria.

The three-night camping event included science and music shows that continued into the evening

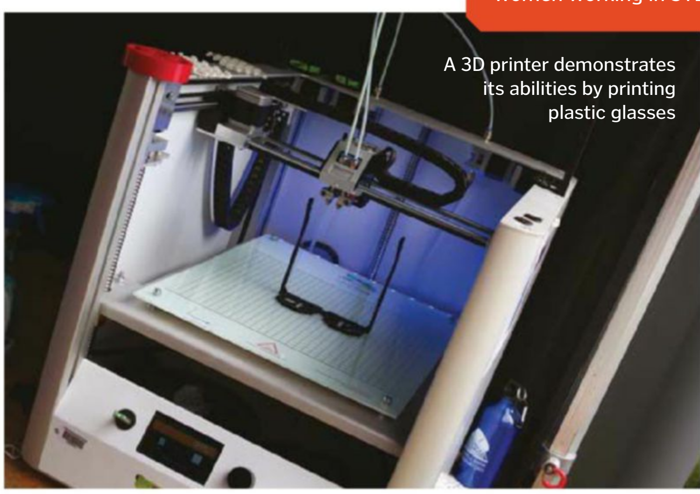
The Wellcome Trust Centre set up engaging games to explain the concepts behind their research

Celebrating Women of Science

Rhys Archer, a postgraduate student, launched the Women of Science campaign to change the way we speak about science. Rather than focus on the education and qualifications of researchers, Archer uses photography to share the interests, aspirations, ups and downs of those in scientific fields on a website and on social media. Archer spoke with our team at Bluedot. "I realised there was a lack of female scientists and engineers in the media, and it isn't accurate. I wanted to better represent women working in STEM."

Rhys Archer's campaign seeks to tell the stories of female scientists to inspire younger generations

The festivities were carried out under the iconic Lovell telescope



A 3D printer demonstrates its abilities by printing plastic glasses

Hands-on activities let us get up close to meteorites under the microscope

The festival gave everyone the opportunity to really engage with science

COMPETITION WINNER

FOR OUR 100TH ISSUE WE RAN A PHOTO CONTEST TO WIN AN AMAZING PRIZE BUNDLE. THANK YOU TO EVERYONE WHO ENTERED – WE RECEIVED HUNDREDS OF ENTRIES. HERE ARE JUST A FEW OF OUR FAVOURITE SHOTS...

And the **WINNER** is…

A huge congratulations to

EVIE-BETH THOMAS!

You have won the mega bundle of gadgets, toys, tickets and books – we hope you enjoy them!

Josiah Zayner

We speak to Josiah Zayner about leaving the world of traditional science to make the field of synthetic biology accessible to the public

Josiah Zayner is a global leading pioneer for the biohacking movement. He is most well known for his work to crowdfund the gene-editing tool CRISPR to provide this innovative biotechnology to the general public. After completion of his PhD in Biophysics from the University of Chicago, he spent two years as a researcher at NASA before starting his company The ODIN. The business runs out of his garage, selling kits that allow individuals to experiment from their homes.

Where did your interest in DIY biology and biohacking come from?

I grew up in the 1990s computer hacker scene. It was a really interesting time because the internet and computers were only just starting to get popular from a personal perspective. Do you remember the first time you used the internet? I remember really vividly. My friend across the street got a computer and his dad had AOL and we logged on. I really got into computers and I started hanging out with what people call computer hackers – people back then were just really interested in computer stuff. We chatted online and taught ourselves how to program and about all the technology. We were just teenagers but we could program better than most adults. When the dotcom bubble burst happened, I turned my focus to biology.

What influenced your decision to step out of the traditional laboratory and start your own up?

Through graduate school and working at NASA, what I really noticed is that there is no access to information and knowledge. It's crazy, but at NASA somebody would publish a scientific paper about how we used a Martian rover to analyse a particular sample, and would publish it in a fancy science journal, but we couldn't even access it because the government couldn't afford the subscription prices for these journals. And I thought 'How is that science? There has to be a better way to do this.'

What were you doing at NASA?

At NASA I did synthetic biology. We engineered bacteria and yeast to make it easier to live on Mars for long-term space travel. I remember one time when my supervisor said to me, "Hey, can you not work in the laboratory so much?" And I just couldn't believe it. This is science, in 2015, where people argue about whether or not someone should work in a lab instead of thinking how can we get *more* people working in the lab. We are supposed to challenge conventions based on data and rigorous testing, but how can we do that without performing the experiments thoroughly in a lab?

What does The ODIN do?

We are a consumer genetic engineering company. We are trying to give the consumer – someone who isn't a professional – access to supplies that normally they wouldn't be able to get without paying ridiculous prices.

There are so many difficulties to overcome just to do a little science in your home. You can't buy supplies from anyone; you can't access scientific literature; most people you email – scientific professors – won't respond. It's a constant battle for people who are trying to do science.

The ODIN tries to make that easier. We try to be responsive and help people out with their projects; we write protocols and guides to simplify things, so people don't have to understand these super-complex papers.

Why did you choose to provide CRISPR to the general public?

The first reason was because whenever we hear about these new technologies, you hear people say, "It's only two years away". None of us ever really get to experience it because two years away means it's more like 20 years away. I thought, 'What do I know?' I know synthetic biology and genetic engineering, so if I could understand how CRISPR works and make it accessible to people, then people could actually experiment and play with this technology that we thought was years away. I thought that was a really cool idea.

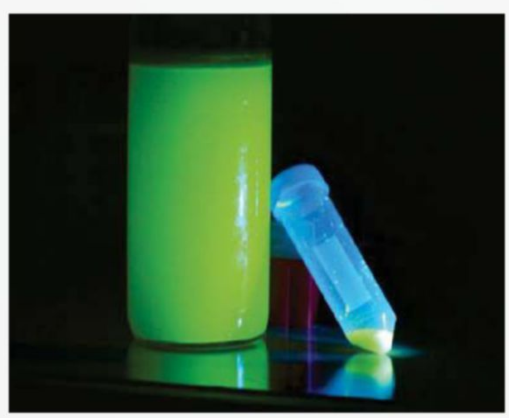
What is The ODIN working on right now?

One big thing we are making a push towards is people working with yeast – so something people can actually create something with. One of the big problems that we've seen is that with genetic engineering and synthetic biology, people do an experiment and then that's it. We want to use this technology as part of people's lives to interest them in science. We plan to release lots of experiments and equipment along those lines, allowing people to change the colour of yeast – you can even use florescent colours – as well as changing the aroma and the flavour.

You are also involved with the Open Insulin Project. What is the idea behind this?

Diabetics can live normal, healthy lives if everything is functional, but their life depends on whether or not a company can provide them

Zayner operates his company from his homemade laboratory based in his garage



The ODIN's products include kits to genetically engineer yeast to brew fluorescent beer

Zayner's CRISPR kits can be bought for £120 ($159) and include all sequence and cloning detail to perform custom genome engineering at home

with insulin. As you can imagine, in areas where people don't have easy access to these medications, people can suffer serious side-effects, or even die because of it. The way they make insulin now involves genetic engineering – they take the gene for human insulin, they put it into bacteria and grow it up, and then extract the insulin protein from the bacteria. The process in theory is really simple, because getting hold of bacteria and putting the insulin gene in the bacteria is not complicated. If more people knew how to purify the insulin from the bacteria, easily, and make it open-source, it could create a medicine that is extremely accessible for people.

US readers
Zayner will be speaking at the BioHack The Planet 2017 conference, which takes place on 25-26 August in Oakland, California, at The Omni Commons

How far along is that project at the moment?
It's really far! Right now we have actually been able to make the insulin protein, detect that we have made it, and even purify it a bit. There is one final step – for the insulin protein to be functional, it actually has to be separated into two parts. This is the last step that people are trying to figure out in order to create the first prototype.

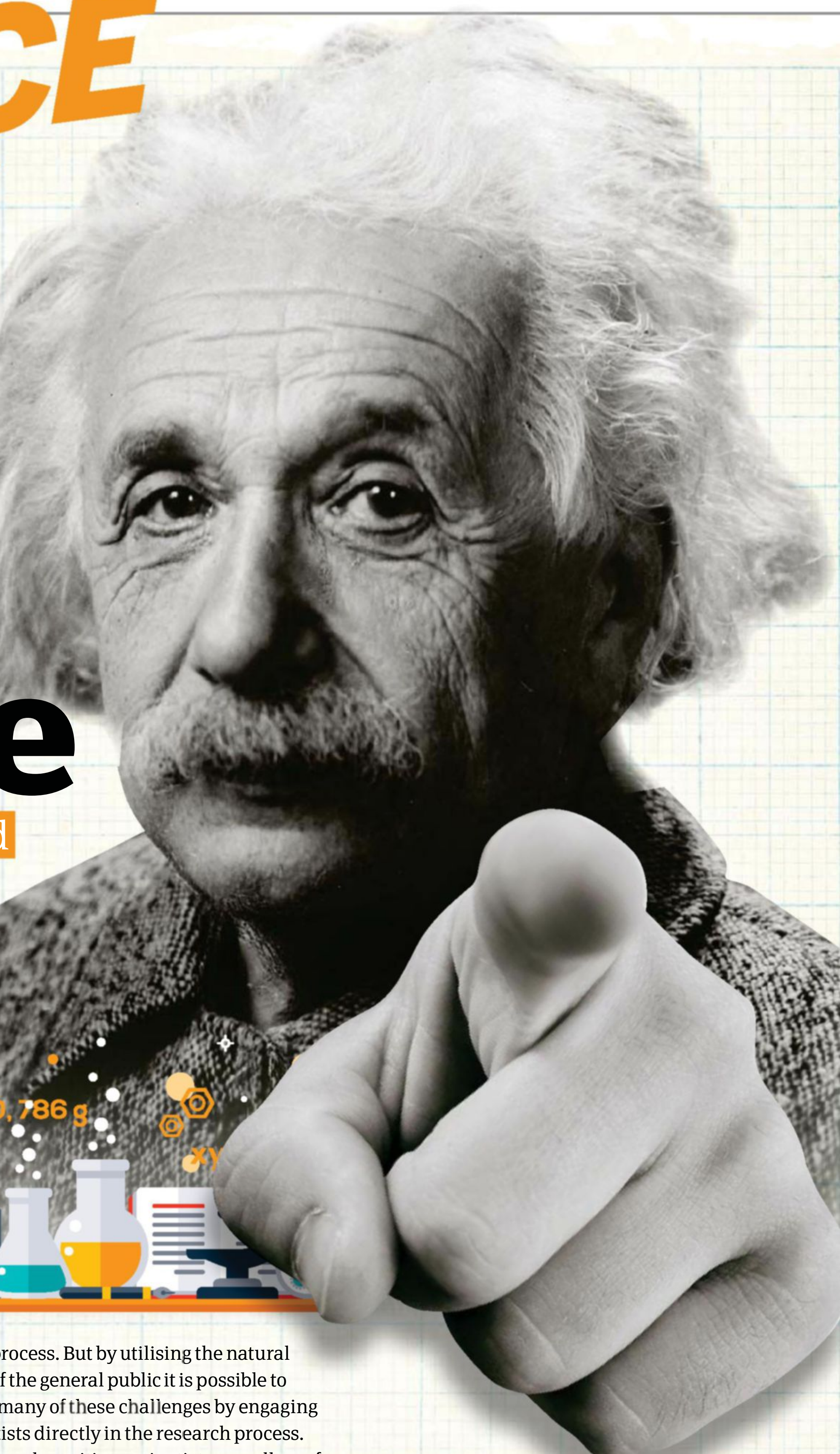
Where do you see the future for this involvement of the general public in real scientific experimentation and advancement?
I think right now everything is in this phase of growing. There are a lot of people buying our kit just to see what it's about and to try it out. I think these people, who are doing experiments at home, they aren't inhibited by what a scientist says is possible or not possible or what you can't or can't do. That's the way science should be, right?

What advice would give to people wanting to get into DIY biology?
I have a tattoo that says "Create something beautiful", and that is the advice I would give someone. Create something beautiful, whether it is within science or art or whatever, all of the disciplines are really intertwined. But if you can do something and want to do something, create something beautiful, whatever that is to you.

"If you can do something and want to do something, create something beautiful, whatever that is to you"

Head to **howitworksdaily.com** to read the interview in full

SCIENCE NEEDS YOU!



Citizen Science

Amateur scientists have started a revolution by opening the doors to scientific innovation and research, allowing the public to get involved

Innovation and research have relied on public participation in science for centuries. It was a musician who discovered the planet Uranus in the 18th century by making his own telescope with mirrors composed of copper and tin.

Recent decades have seen science move into a convention where engagement in the subject can only be done through institutions such as a university. Citizen science provides an opportunity for greater public engagement and the democratisation of science.

In the information era, large data sets, small teams and financial restrictions have slowed scientific process. But by utilising the natural curiosity of the general public it is possible to overcome many of these challenges by engaging non-scientists directly in the research process.

Anyone can be a citizen scientist, regardless of age, nationality or academic experience. You don't even need any formal training, just an inquisitive mind and the enthusiasm to join one of the thousands of citizen science projects to generate new knowledge and the means to understand a genuine scientific outcome.

Scientists have employed a variety of ways to engage the general public in their research, such as making data analysis into an online game or sample collection into a smartphone application. They've implored citizen scientists to help with bug counting and categorising cancer cells, and even identifying distant galaxies.

This form of accessible science means that great minds are able to join the race to create and develop projects with the potential to change the

world. A citizen science-based approach can extend the field of vision and include more ideas and different brains to problem-solve and create, making innovation faster and more effective.

The rise of citizen science has grown alongside the rise of do-it-yourself biology laboratories. These groups of people around the world are part of a rapidly expanding biotechnological social movement of citizen scientists and professional scientists seeking to take discovery out of institutions and put it into the hands of anyone with the enthusiasm.

There are around 40 official do-it-yourself biology centres across the globe in locations including Paris, London, Sydney, and Tel Aviv. They pool resources, collaborate, think outside the box, and find solutions and ways around obstacles to explore science for the sake of science without the traditional boundaries of working inside a formal setting. So is it time to take the Petri dish out of the laboratory and into the garage?

Citizen scientists on social media

Follow some of the people involved in incredible science projects

Josiah Zayner
@4LOVofScience

Zayner pioneered the crowdfunding for DIY CRISPR kits to provide wider access to gene technology. He explores scientific questions creatively and carries out his own experiments in his garage. Check out our interview with Zayner on page 12!

Lucy Robinson
@littlelocket

Citizen science programme manager at the National History Museum, Lucy Robinson arranges a wide range of projects, from collecting samples of bacteria for DNA analysis to recording observations about bluebells.

Maria Chavez
@bioCURIOUSlab

Maria is a biohacker and the executive director of Biocurious, a community biology laboratory in California. Her work includes an Open Source project to create cheese from genetically engineered yeast. She is also involved in the Open Source Insulin Project.

Shawna Pandya
@shawnapandya

Shawna is a Canadian neurosurgeon and taekwondo athlete who has been selected as one of two candidates to fly in the Citizen Science Astronaut programme.

Alice Sheppard
@PenguinGalaxy

Alice is an enthusiastic citizen scientist and science communicator in the field of astronomy. She also co-founded the Cardiff and Hackney 'Skeptics in the Pub' group.

DIY biology

Get hands-on with science experiments at your local laboratory

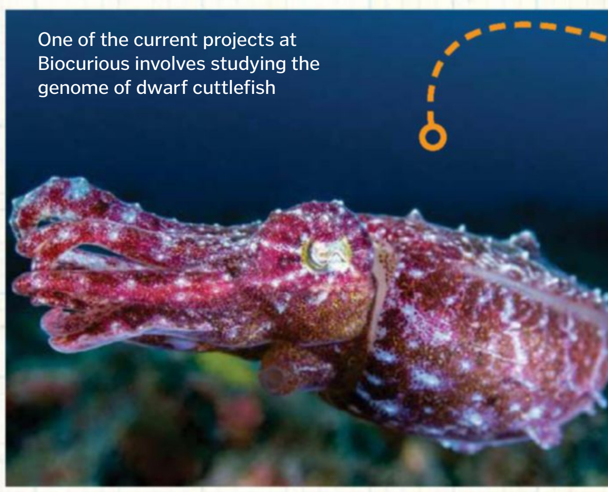
London Biohackspace

biohackspace.org

London Biohackspace is a non-profit, community-run molecular and microbiology laboratory situated within the London Hackspace. They encourage amateurs and professionals from any background to explore the field of science.

Co-founder Samantha Thompson gave us a tour of the space she has built. The lab contains shelves of chemicals, plus experimental, sterilisation and safety equipment, including a setup for detecting and measuring DNA. We also met with an exchange student from India who, frustrated with the time taken to diagnose bacterial infection, has built a prototype of a microwave-sized machine to speed up the process.

The Hackney based laboratory welcomes new members throughout the year



One of the current projects at Biocurious involves studying the genome of dwarf cuttlefish

Biocurious

biocurious.org

Biocurious is the world's first Hackerspace for biology, built in the heart of Silicon Valley, and they are pioneering the field of DIY biology. The entirely volunteer-led laboratory provides a hub for everyone with an interest in scientific innovation, from those with no scientific background to professional scientists and artists.

Their laboratory is kitted out with molecular genetics machines, an autoclave, pipettes, florescent microscopes, protein purification systems and glassware. Their previous projects have included building their own inverted optical fluorescing microscope. Currently, their projects include designing glow-in-the-dark plants, developing a real vegan cheese by engineering yeast to produce milk, and a cuttlefish RNA sequencing genome project.

The power of the crowd

In addition to utilising the power of crowds as the source of a work force, scientists who have been held back by funding problems have turned to crowdfunding. This has allowed amazing ideas that would have been stopped due to financial barriers to continue with the support of money from the general public. Websites such as **experiment.com** and **crowd.science** can be used by scientists to upload information about their project, including photos and videos, and a break down of costs to complete their research. They are then supported by individuals in the public who wish to help them see their research through to completion.

KEY Humanitarian & human activity · Nature & environment · Space · Biology & medicine

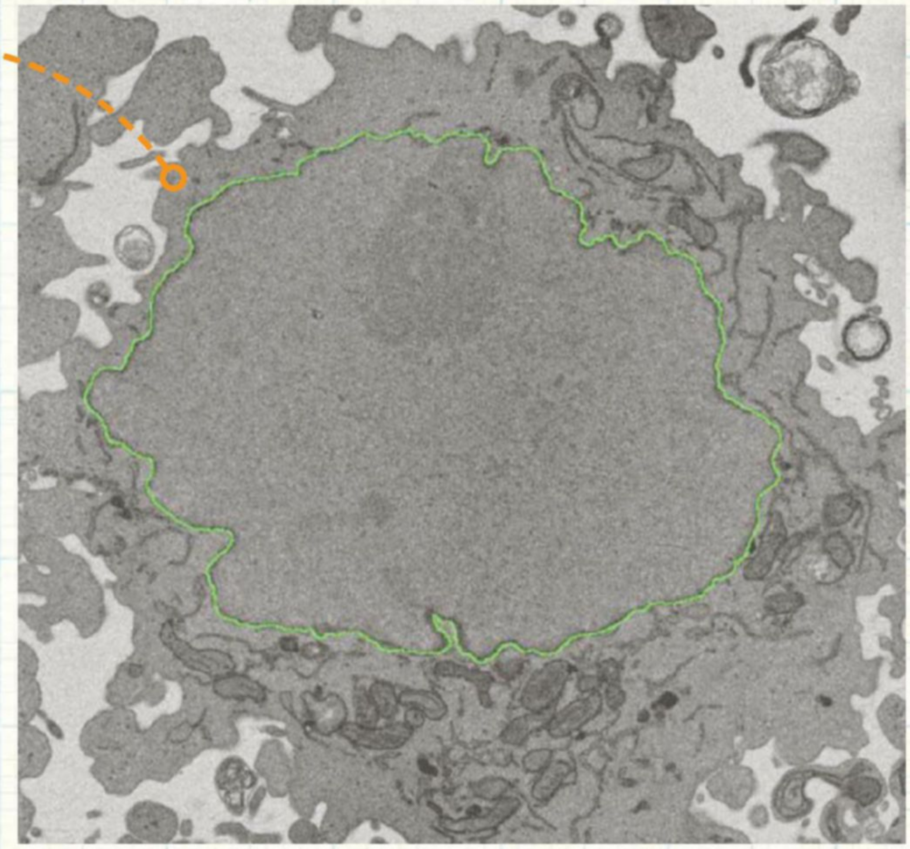
Etch a Cell

daily.zooniverse.org/category/projects/etch-a-cell/

This exciting biomedical project from a research group at Francis Crick Institute in London uses electron microscope photographs to look at hugely magnified cells. Citizen scientists are provided images of slices of cells to draw around the nuclear envelope (the membrane that surrounds the cell nucleus). This data is then used to create a 3D profile of the nucleus to provide a better image for understanding the role of nucleus shape in relation to disease.

Scientists believe that changes in the shape of the envelope could be involved in causing common diseases, as it has such a vital role in the functioning of the cell – it holds the entirety of the genetic information controlling the activities of the cell. The data from this study is used in collaboration with other groups to further the understanding of diseases such as cancer, HIV and diabetes.

"Data from this study will help us better understand diseases like cancer, HIV and diabetes"



Citizen scientists outline the nuclear envelope (green) of cell slices in scanning electron microscope images such as the one above

There are about 19 different species of bumblebee in the UK

The Big Bumble Bee Discovery

www.britishscienceassociation.org/the-big-bumblebee-discovery

In 2014, over 27,000 bumblebees were counted in a project involving more than 30,000 people. The national citizen science project The Big Bumblebee Discovery was led by Dr Helen Roy, Dr Michael Pocock and the Centre for Ecology and Hydrology.

The ecologists focused on the diversity and abundance of bumblebees in relation to their surroundings. The citizen scientists involved in the research, including more than 400 schools, were asked to monitor a lavender plant for bumblebee sightings and upload the results to EDF Energy's 'The Pod'. The data is being used to explore the links between environmental changes and the affects on insect populations. The results have surprisingly found that bumblebee sightings are more common in urban areas. There were also higher numbers of bees recorded when it was sunny and breezy.

Quake-Catcher Network

quakecatcher.net

The QCN provides software to turn existing laptops and desktops into the world's largest strong-motion seismic network by using your computer's in-built micro-electromechanical systems to detect vibrations.

The Plankton Portal

planktonportal.org

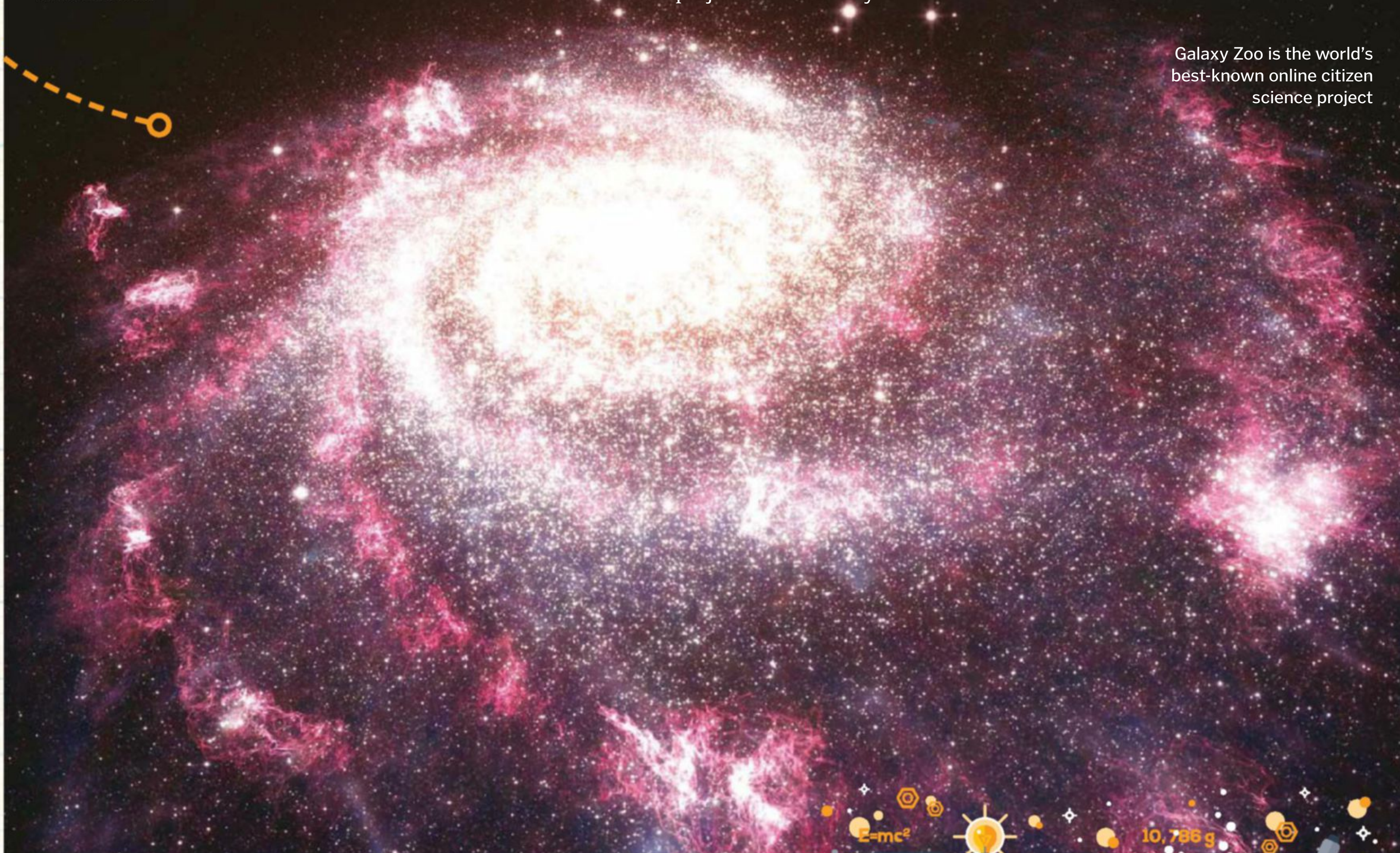
Mark images of plankton from an underwater imaging camera to provide scientists with data about the health of the oceans.

Galaxy Zoo

galaxyzoo.org

Galaxy Zoo has the largest number of scientific publications based on data from citizen scientists, with more than 50 million classifications having been received in the first year from more than 150,000 citizen scientists. The volunteers involved in classifying the images are asked a series of questions about the number of spiral arms, the size of the galaxy, and how to identify if the galaxy is an elliptical, merger or spiral.

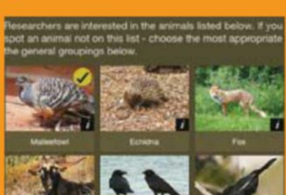
The source of the images includes the United Kingdom Infrared Telescope (UKIRT) and Hubble. Tens of projects are currently actively using the data from Galaxy Zoo. These include a study to measure dark energy and a project that is building a sophisticated simulation of the beginning of the universe. Galaxy Zoo has seen several projects to completion but is ongoing with big plans for the future.



Galaxy Zoo is the world's best-known online citizen science project

Get involved!

Data you gather can help scientists protect the environment



Wildlife spotter

You can contribute to the protection of threatened species in Australia by identifying animals that have been photographed by secret camera traps. As of July 2017, nearly 4 million animals have been identified by over 58,000 volunteer spotters.

wildlifespotter.net.au

Weddell Seal Count

A seal colony is being photographed every ten minutes using an automated camera in Antarctica. Volunteers identify Weddell seals in the images to help researchers better understand their activity cycles.

www.zooniverse.org/projects/slg0808/weddell-seal-count

Snow spotter

Help hydrologists from the University of Washington analyse the pattern of forest snowfall by classifying photos. These allow scientists to better understand the overall water supply for the dry season.

www.zooniverse.org/projects/mozerm/snow-spotter

Chimp & See

How do chimps really act in the wild? Scientists need your help to find out. Identify species and mark the behaviour of chimpanzees by studying images and watching video feeds captured from their natural habitats in Africa.

www.chimpandsee.org

Zen of Dragons

Identifying objects accurately is a tricky task for a computer program, but with Zen of Dragons you can help train an algorithm to recognise dragonflies and damselflies from images.

www.zooniverse.org/projects/willkuhn/zen-of-dragons

KEY Humanitarian & human activity | Nature & environment | Space | Biology & medicine

Moon Zoo data.moonzoo.org

Moon Zoo was a pioneering citizen science project that was launched in May 2010 and completed by June 2015. During the five years of data collection, users identified, classified and measured shapes on the Moon's surface using high spatial resolution images from the Lunar Reconnaissance Orbiter Camera (LROC).

The study focused on the area around the Apollo 17 landing zone, with the aim of recording the number and location of craters, boulder distributions and various geomorphologic features of interest. The preliminary results data was accepted for publication in the scientific journal *Icarus*.

The study region was chosen because it is incredibly geomorphically diverse and includes crater fields, uplands and downslopes

"During the five years of data collection, users identified, classified and measured shapes on the Moon's surface"

Hurricane Matthew destroyed up to 90 per cent of some areas and left 1.4 million people requiring humanitarian aid

Humanitarian OpenStreetMap Team

hotosm.org

After Typhoon Haiyan struck the Philippines in 2013, over 1,500 volunteers were rallied together from behind their computers to make over 4.2 million edits to the online open global map OpenStreetMap. The citizen scientists involved in this disaster relief profile marked buildings that had been damaged or destroyed in order to create a map of the worst affected areas of the islands.

The volunteer group have since built on their remote damage assessment technique and have assessed the impact from Hurricane Matthew in Haiti. They have also gone on to develop long-term projects, including the malaria elimination campaign. The project works with Clinton Health Access Initiatives malaria programme to map the most populated areas in southern Africa, Southeast Asia and central America.

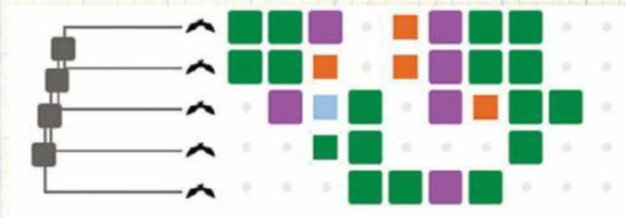
Phylo DNA Puzzles

phylo.cs.mcgill.ca

DNA sequences are written as long strings of genetic code, which at first glance seem like nothing other than a jumble of letters. So when scientists need to compare DNA from different species they use computer algorithms to recognise areas where the DNA sequences match. Jérôme Waldispühl explained why this process is important to **How it Works**:

"If it is found across multiple species, it means it is preserved by evolution. If that's the case, it is likely because this pattern is used to encode a function in our genome."

Waldispühl and his team built Phylo DNA puzzles into a tile-matching game that can be more accurate than the current computer programs. Participants move the bricks horizontally to create columns with the same colour to identify conserved regions of sequences across species.



This game has been designed so citizen scientists can help those who are working in genetics

The Plastic Tide

theplastictide.com

This project entails tagging plastic litter on drone photographs of beaches to teach software how to identify it automatically. The project helps to understand the amount of plastic and build a program to automatically detect the litter.

Get involved!

Take part in some out-of-this-world research projects

Globe At Night

This campaign aims to measure the impact of light pollution. Citizens measure the brightness of the sky and submit their observations to an online database. This valuable source of data helps studies, such as how light pollution affects bats' feeding habits.

www.globeatnight.org

SETI@home

In collaboration with the University of California, this project uses the internet to aid the Search for Extraterrestrial Intelligence (SETI). Citizen scientists can download a free program that monitors and analyses radio telescope data.

setiathome.berkeley.edu

Mars Mapper

You can help identify the best regions to look for evidence of historic or even current life on the Red Planet. Volunteers identify the 'newest' features on Mars, such as young dunes and recent volcanic eruptions, by circling craters.

cosmoquest.org/x/science/mars

Planet Hunters

Use light curve data from NASA's Kepler spacecraft to help identify new planets that are missed by automatic detection. The principle is that, as a planet passes in front of its star, its starlight appears to dim, which can be detected by Kepler and then analysed.

planethunters.org

GLOBE Observer

This app allows citizens to make observations about the environment to help professional scientists in their research. This includes the project 'Cloud' that helps to record sky observations to compare with satellite images.

observer.globe.gov

KEY Humanitarian & human activity · Nature & environment · Space · Biology & medicine

Bash the Bug

bashthebug.net

Bash the Bug launched in April 2017 and seeks to change the way tuberculosis is diagnosed and subsequently treated.

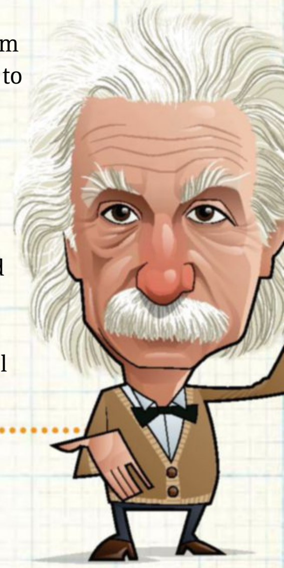
In an age where the prevalence of antibiotic resistance is a rising concern, understanding which ones are effective against particular infections is vital for effective patient treatment. Citizen scientists are provided images of Petri dishes that have two plates with no antibiotics and six dishes that have been treated with varying doses of an antibiotic. Volunteers involved in the project identify which dose plates are showing tuberculosis growth.


Antibiotic resistance is an increasing threat to global health

Global Xplorer

globalxplorer.org

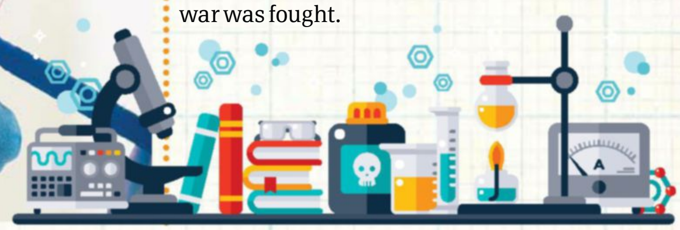
This online platform allows individuals to analyse the huge wealth of satellite imagery available to archeologists. The project was launched by Dr Sarah Parcak, whose techniques have helped locate 17 potential pyramids, 3,100 potential forgotten settlements and 1,000 potential lost tombs in Egypt.



Operation War Diary

operationwardiary.org

This transcribing project seeks to provide information about the experience of named individuals in the Imperial War Museum's Lives of the First World War project. You can help provide academics with a large amount of data to help them gain a better understanding of how the war was fought.

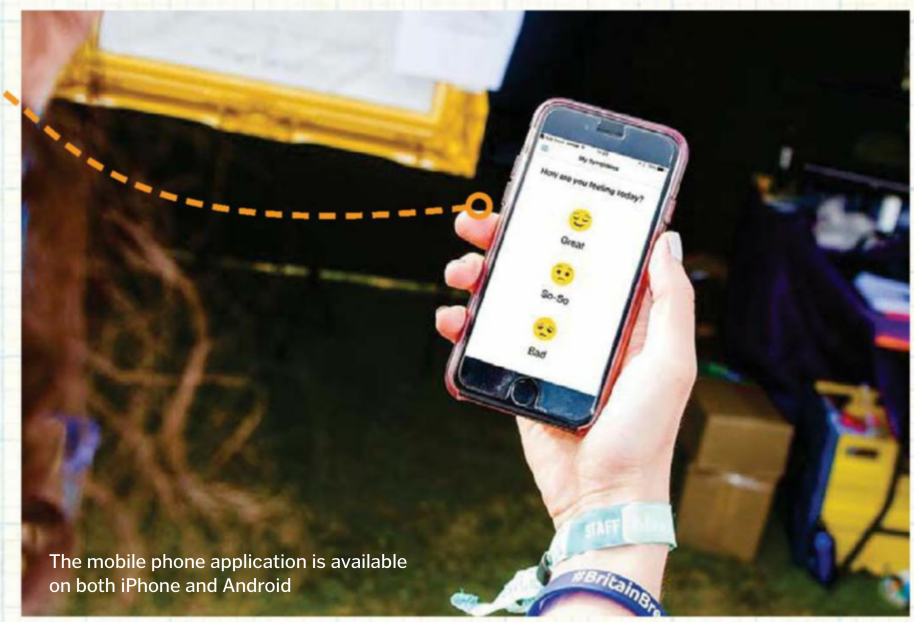


Britain Breathing

britainbreathing.org

This project is a collaboration between the British Society for Immunology, the Royal Society of Biology and the University of Manchester. The team behind this citizen science project developed a free app to allow anyone to record their allergy symptoms in just a few clicks to gather data nationwide. The team intends to investigate what factors affect seasonal allergies and examine why they are on the rise.

We spoke with Dr Sheena Cruickshank to find out more. "Allergies are increasing in the UK and in other countries and we don't really know why. Genetics play a bit of a role, but the biggest role seems to be that of the environment." Dr Lamiece Hassan, the public involvement and governance research officer, points out that approximately one in four people suffer from seasonal allergies.



The mobile phone application is available on both iPhone and Android

Cell Slider

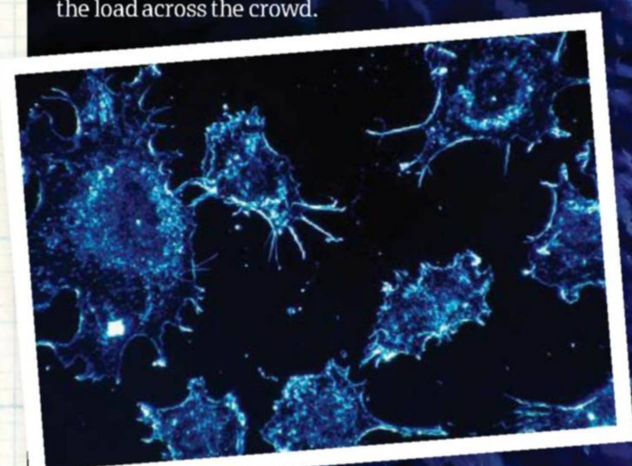
cellslider.net

Cell slider was a successful project developed with Zooniverse and Cancer Research UK and culminated in a paper published in the journal *EBioMedicine*.

Citizens involved in the project were provided with images of tumours and were asked to identify cancer markers. When the researchers compared the accuracy of the non-specialists in comparison to the pathologists, they found the non-specialists' work was viable and accurate.

The project was wildly successful, with hundreds of visitors using the website every day and a total of 1,939,984 classifications were provided by citizen scientists for analysis.

This groundbreaking project has demonstrated that even with minimal training, citizen scientists can accurately identify estrogen's receptor expression in breast tumours. In addition, the project results suggested that the involvement of the general public could reduce the bottlenecking issues in large studies by allowing more data to be processed and sharing the load across the crowd.



Citizen scientists could help advance cancer research

"When researchers compared the accuracy of the non-specialists to the pathologists, they found the non-specialists' work was viable and accurate"

How hands work

Our hands are complex feats of biological engineering

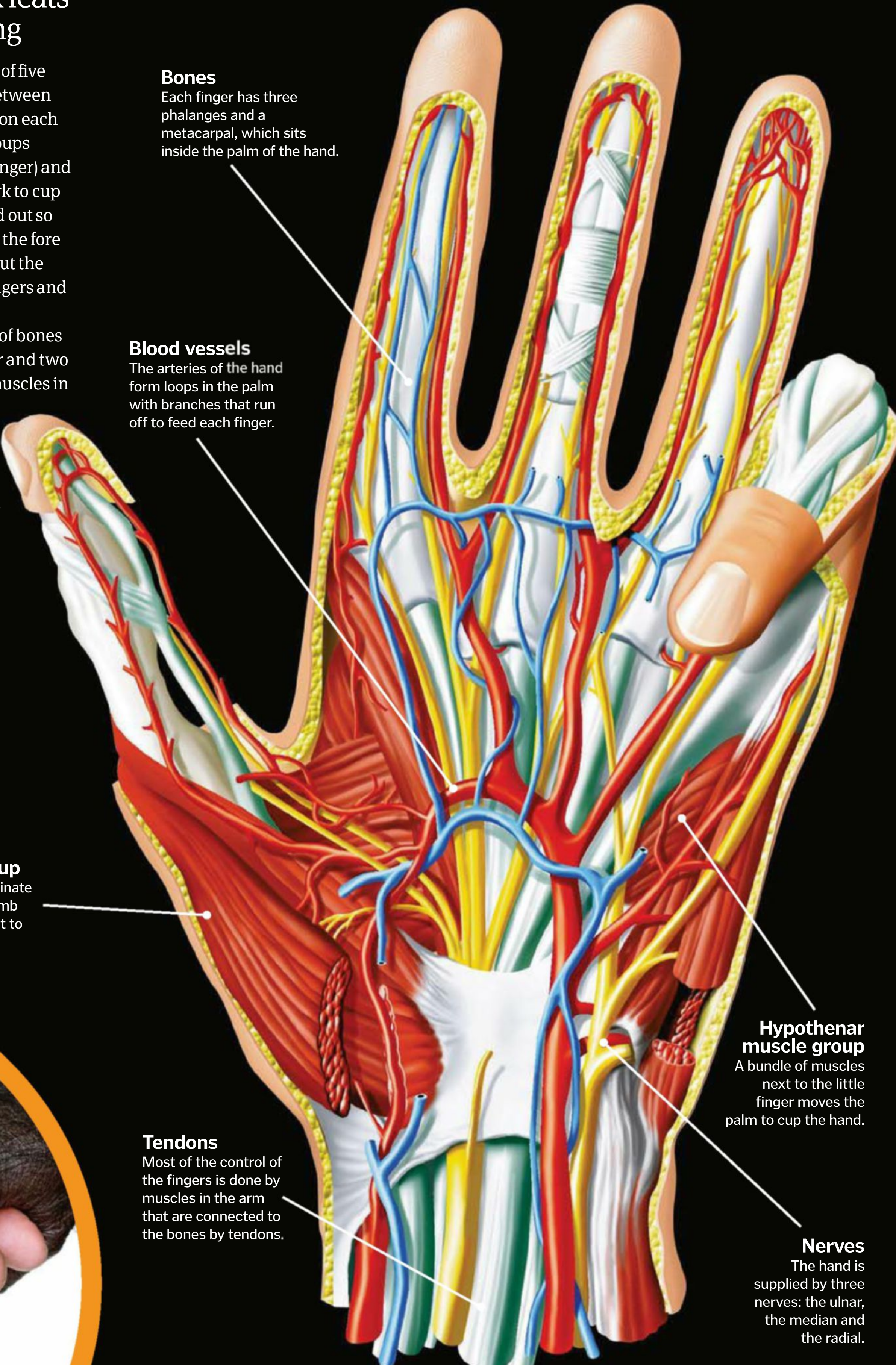
The palm of the hand is made up of five bones called metacarpals. In between are the interossei muscles, and on each side of the palm are bulging muscle groups called the hypothenar (near the little finger) and the thenar (near the thumb). These work to cup the hand and to move the thumb in and out so that it can grip. The bones belonging to the fore and middle fingers don't move much, but the ones connected to the little and ring fingers and the thumb are much more mobile.

The fingers themselves are made up of bones called phalanges – three for each finger and two for the thumb. They are connected to muscles in the forearm by tendons that run through the wrist. The flexor tendons run up on the underside through a space called the carpal tunnel – they bend the fingers. The extensor tendons come across the top of the wrist – they pull the fingers straight.

All of this movement is controlled by three nerves: the median, radial and ulnar. The median nerve supplies the thumb, the index and middle fingers, half of the ring finger and the palm of the hand. The ulnar feeds the other half of the ring finger and the little finger, and the radial looks after the thumb and the back of the hand.

Hand anatomy

Discover the bones, muscles, tendons and nerves inside the human hand




Only a few other animals have opposable thumbs like ours

The science of tea

Five essential steps to creating the perfect cuppa – explained by science

What's in a drip?

We take a closer look at intravenous (IV) fluid therapy

Intravenous literally means 'in vein', and it's the most direct way to get something into the body. IV therapy is used to replace lost fluids, rebalance salts and deliver medications. The most commonly used fluid in an IV drip is a saline solution: a sterile mix of salt and water designed to replicate the saltiness of normal body fluids. It's normally delivered slowly, straight into a vein in the back of the hand or the inside of the elbow. Additional molecules can be added to the liquid, including sugars or drugs, allowing a constant dose to be administered gradually over a long period of time.

In an emergency, IV fluids can also be given rapidly for 'fluid resuscitation'. If a patient has lost a lot of fluid from their blood, through dehydration or bleeding for example, blood pressure can drop so low that blood can't get around the body. This is known as 'hypovolemia', which literally translates as 'under volume blood'. IV fluids can quickly top up the system, restoring normal blood pressure.

A drip can be used to deliver fluids, salts and medical treatments

HOW TO SPOT BAD SCIENCE

Call out those crazy claims with our quick guide to fake facts

1. RESIST CLICKBAIT

OMG!!

Outrageous headlines get clicks, but the articles underneath don't always back up the claims. It's hard to summarise science in five or ten words, so don't take the top line at face value.

2. DON'T JUMP TO CONCLUSIONS

Just because something worked in a lab doesn't mean it'll work in the real world. The science might be solid, but if the conclusion sounds too good to be true, it probably is.

3. SPOT INDUSTRY FUNDING

Look twice if a sugar study was funded by a drinks brand, or a smoking study by a tobacco company. It doesn't always mean bad science, but it's worth bearing in mind.

4. LOOK OUT FOR CORRELATION

Did you know that more people drown as ice cream sales go up? Just because two things happen at the same time doesn't mean that one causes the other.

5. BE WARY OF SPECULATION

???

If scientists say 'might', 'could' or 'may', it often means that they don't yet have all of the evidence. More work is often needed to expand brand new findings.

6. CHECK THE SAMPLE SIZE

Look carefully at the number of people tested in a study. If results are based on a sample of thousands of people, they're likely to be more reliable than results based on a sample of five.

7. WATCH OUT FOR BIAS

Study groups can't always represent the whole population. If a test has been done on one group of people, the results won't necessarily apply to another group.

8. CHECK FOR CONTROLS

It's impossible to know if something has changed if you've got nothing to compare it to. Good studies should have a control that scientists can refer to as their baseline.

9. LOOK FOR BLINDING

Blind experiments help to reduce conscious and unconscious bias. Where possible, the participants, and sometimes the scientists themselves, should not know which is the test group and which is the control.

10. FIND THE WHOLE STORY

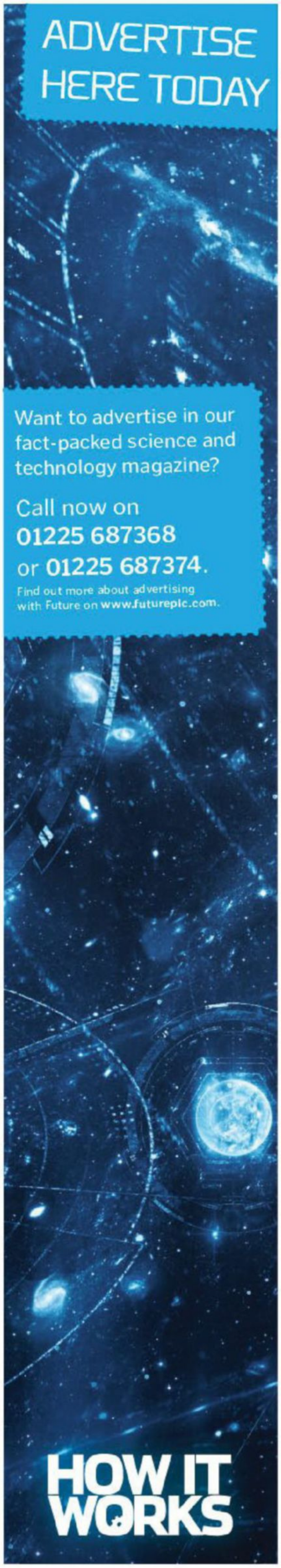
Sometimes only part of the story is told, particularly when science news is picked up by the media. But one finding on its own isn't enough – science is about the big picture.

11. BEWARE ONE-OFFS

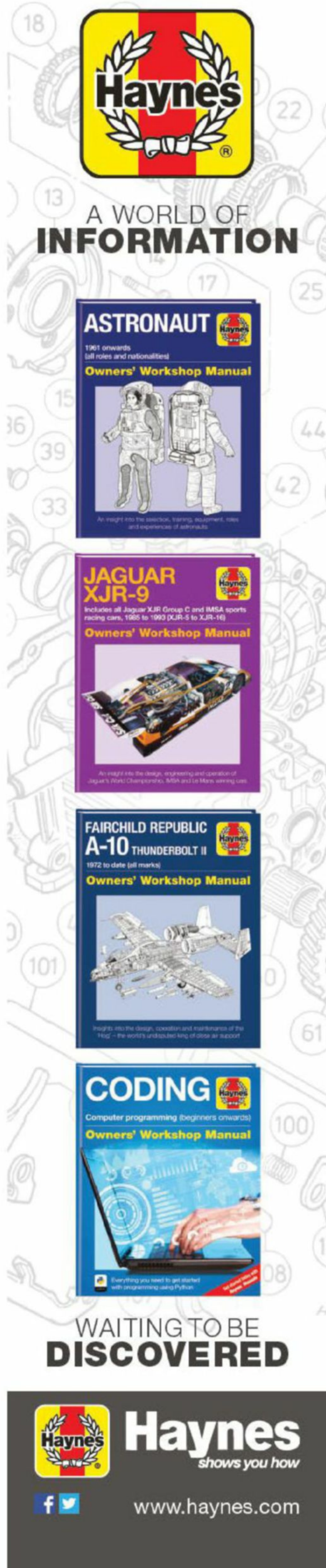
If there's only one study to back up an outlandish claim, be cautious. The strongest science has lots of evidence generated independently by different people.

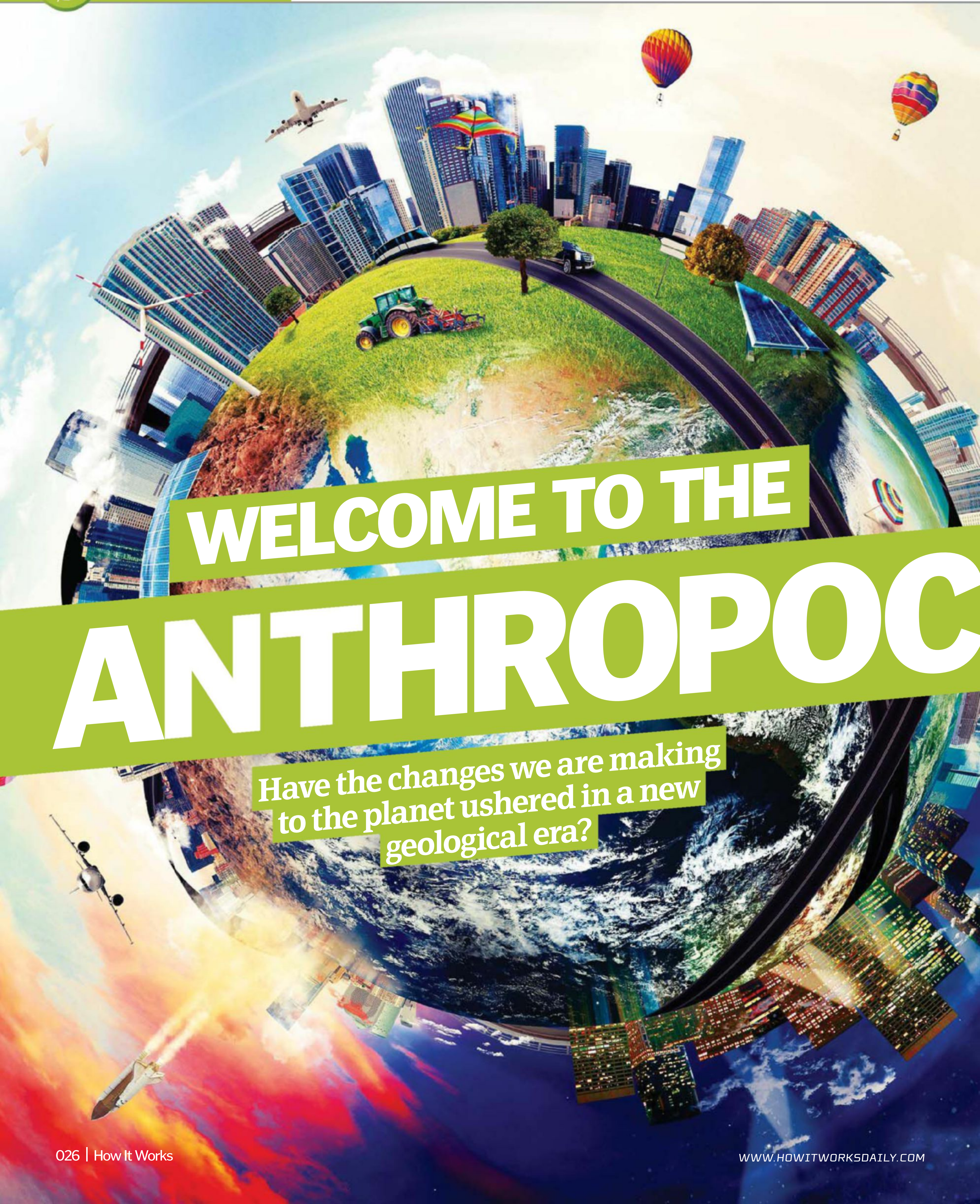
12. FIND THE SOURCE

The best question to ask is where did this come from? Good science will have been checked thoroughly by other experts in the field and should be published in a peer-reviewed journal.


ADVERTISE HERE TODAY
Want to advertise in our fact-packed science and technology magazine?
Call now on 01225 687368 or 01225 687374.
Find out more about advertising with Future on www.futureplc.com.
HOW IT WORKS


techcamp .org.uk
Inspiring Tomorrow's Inventors
EXCLUSIVE NEW COURSES ...
Turn a toy into a fully programmable 'bot in Robot Brain Surgery
Move over Bond ... make your own gadgets in Gadget Factory
Build advanced robots and battle them in Robot Inventor
Design & build a HiFi audio system in Bluetooth Speakers
Build & Fly Your Own Advanced Drone in Quadcopters
Design your own games and game art in Game Design 1, 2 & 3
NEW VENUES for 2017 ...
• Abingdon
• Coventry
• Chelsea
• Harrow
• Weybridge
• Winchester
Come as a day camper or join hundreds of other young people from around the UK and overseas at our flagship residential camps where you also spend evenings playing laser tag, disassembling electronics and even have your own en-suite room.
Want to Know More?
Tech Camp is the UK's original camp of its kind and remains the only one specialising in teaching coding through advanced take-home projects. It's perfect for creative youngsters who like making things (or taking them apart!) or show those who are forever playing games how to start designing their own.
We have tutors from institutions like Cambridge & Imperial, maximum groups of eight, and exclusive courses not available anywhere else.
www.techcamp.org.uk info@techcamp.org.uk 0118 380 5678


Haynes
A WORLD OF INFORMATION
ASTRONAUT
Owners' Workshop Manual
JAGUAR XJR-9
Owners' Workshop Manual
FAIRCHILD REPUBLIC A-10 THUNDERBOLT II
Owners' Workshop Manual
CODING
Owners' Workshop Manual
WAITING TO BE DISCOVERED
Haynes shows you how
www.haynes.com



WELCOME TO THE ANTHROPOC

Have the changes we are making to the planet ushered in a new geological era?

The planet we call home has been around for 4.6 billion years, and a lot has changed in that time. Continents have drifted, climates have fluctuated, species have come and gone and, of course, humans have evolved. All of these milestones are well documented in changes in the fossils and chemical signals found in Earth's layers of rock, and this has enabled geologists to divide the planet's timeline into several distinct eras.

You are probably familiar with the Triassic, Jurassic and Cretaceous periods in which the dinosaurs lived, but today we live in what has been officially labelled the Holocene, a name that comes from the Ancient Greek for 'entirely recent'. This epoch began 11,700 years ago after the last major ice age and, for the most part, has featured a relatively stable climate. This has enabled us to plan ahead and greatly improve our way of life by inventing agriculture, harnessing new forms of energy and building cities.

> "Some have suggested the 1950s as the greatest turning point in our impact on the Earth"

However, some scientists are now arguing that the enormous impact all of this human activity has had on the planet has led us into an entirely new geological epoch: the Anthropocene. This term, which roughly translated from Greek means 'the age of humans', was first coined in 2000 by Nobel Laureate chemist Paul Crutzen. Recalling the moment he first came up with the name, Crutzen said, "I was at a conference where someone said something about the Holocene. I suddenly thought this was wrong. The world has changed too much. No, we are in the Anthropocene. I just made up the word on the spur of the moment. Everyone was shocked. But it seems to have stuck."

Indeed, the term has grown in popularity with scientists ever since, having appeared in nearly 200 peer-reviewed journals and even inspiring the name of a brand new academic journal: *Anthropocene*. Nevertheless, it is still not recognised as an official epoch. For that to happen, the International Union of Geological Sciences (IUGS), the professional organisation in charge of defining Earth's time scale, must declare it so. In 2016, the Working Group on the Anthropocene (WGA) voted to formally recognise the new epoch and presented its case to the International Geological Congress, but a final decision has not yet been reached.

In the past, such a decision has taken decades and even centuries to make, as to identify the boundary between distinct eras there must be enough evidence of a signal that occurs globally between layers of rock. For example, the end of the Cretaceous period was identified by a 'golden spike' of the metal iridium that was dispersed in sediments around the world by the asteroid that wiped out the dinosaurs.

Although it is hoped that the Anthropocene could be declared in the next few years, the main problem geologists face is working out exactly when it began. Some argue that it happened thousands of years ago with one of the biggest human led changes: the invention of agriculture.

However, the crops grown by our early ancestors did not have a great deal of impact on the Earth's rock, and the development of new farming practices was relatively gradual. Therefore, another of the more popular arguments puts the date at around 1750 when the Industrial Revolution took hold. At this time the use of fossil fuels led to a significant rise in the amount of carbon dioxide present in the atmosphere, and mining for coal, oil and gas also drastically altered the landscape.

Alternatively, some have suggested the 1950s as the greatest turning point in our impact on the Earth. At the end of the Second World War, old economic institutions began to break down and the world became increasingly more connected. The human population began to grow at an incredible speed, an event scientists commonly refer to as the Great Acceleration, and the nuclear age began to dawn. Some believe that it will be the radioactive signatures deposited into the Earth from these first atom bomb tests that will

These images highlight the levels of deforestation in the Amazon Rainforest in just eight years

help future geologists define the start of the Anthropocene, while others suggest it could be plastic pollution, the soot from power stations or the concrete used for infrastructure. Even the domestic chicken could become the crucial marker, as thanks to our desire for meat and eggs, it has now become the most common bird in the world.

While this more recent date is considered by many to have the most merit, some geologists argue that there is still not enough clear-cut evidence to define the end of the Holocene. Nevertheless, whether there is a physical boundary to be found or not, there is no denying that humans have had a lasting impact on the environment. We may have only existed on Earth for less than 0.01 per cent of its history, but in that time we have irreversibly reshaped the planet far faster than natural geological processes would have done. In fact, more change has occurred in the past century than in the previous 250,000 years of human history, and we show no sign of slowing down.

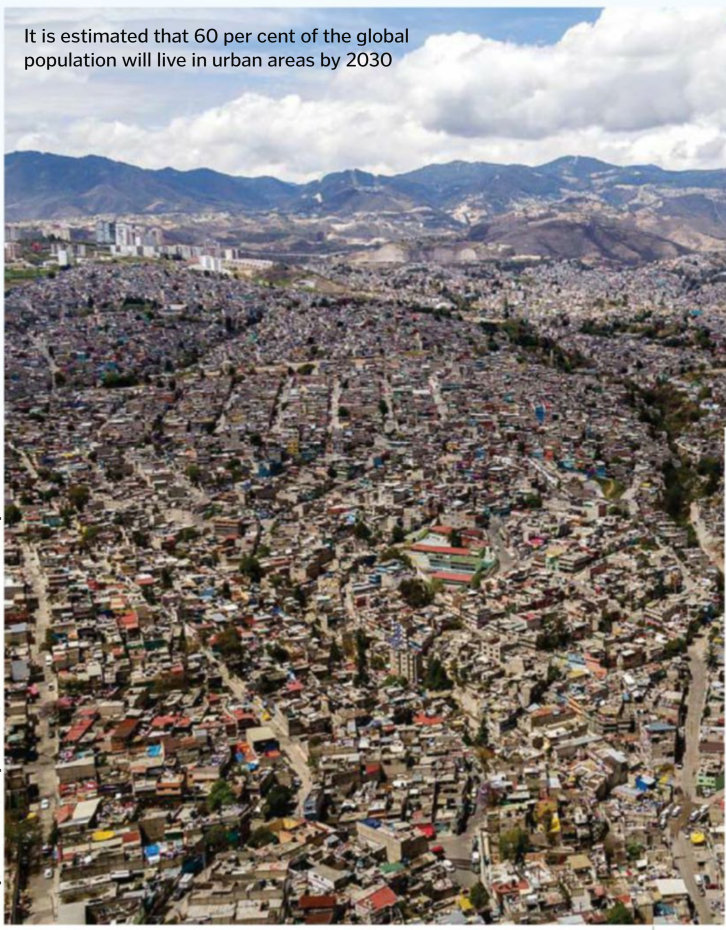
Of course, not all of the changes we have made have been negative. The massive explosion of innovation and discovery in recent years means that most of us now experience a much better standard of living than our ancestors did. Manufacturing jobs have lifted millions of people out of poverty, freeing them from the cycles of starvation and famine that comes from relying on an income from agriculture. Modern technologies can also feed and clothe more people than ever before, as machinery and automation simultaneously speed up and reduce the costs of manufacturing techniques.

Advancements in medicine, such as the development of vaccines and genetic engineering for the development of drugs and gene therapies, have also significantly lowered the death rate, while economic development is helping to reduce the need for larger families and slow population growth. We also know more about our planet and the universe than ever before, enabling us to learn from its history, understand its present and plan for its future.

> "The plants and animals we have no use for are becoming extinct at an alarming rate"

Nevertheless, our quest for better lives has not benefited everyone equally. While overall standards of living are improving, the wealth inequality gap is getting wider as more people in the developing world are forced into low-paying jobs that produce goods for developed countries. Using current modes of production, we can only support a population of two or three billion people who enjoy the same standard of living as those in the United States, yet the global population has risen from 1 billion to over 7 billion since the 1800s.

This is also compounding our impact on the environment. The space needed to accommodate and fuel the growing population has led us to alter more than 50 per cent of the Earth's land by clearing forests, building cities and damming rivers. There are now half as many trees as there were before human's existed, and all of this is resulting in a massive reduction in biodiversity across the globe. The plants and animals we have no use for are becoming extinct at an alarming rate, 100- to 1,000-times faster than if we had no input, and



It is estimated that 60 per cent of the global population will live in urban areas by 2030

Some geologists believe the Anthropocene began on 16 July, 1945, the day of the first atomic bomb detonation (find out more in our Manhattan Project feature on page 74)

Plastics take thousands of years to degrade and may prove to be a signature of the Anthropocene

In 2015, delegates from nearly 200 countries signed the Paris Agreement, pledging to take more action to combat humanity's effects on climate change

this is set to increase further in the coming years. Many scientists argue that is the strongest argument for declaring a new geological era, as when future geologists study the fossil records of this time period, they will see a mass extinction event on par with the five most devastating extinction events in Earth's history, including that which wiped out the dinosaurs.

Another major environmental impact is that of climate change. Since 1750, there has been a sharp increase in the amount of greenhouse gas released into the atmosphere, including carbon dioxide from burning fossil fuels, nitrous oxide from the use of fertilisers and methane from livestock and landfill. This has caused a thinning of the ozone, a protective layer in the atmosphere that filters out harmful ultraviolet radiation from the Sun, which is changing the climate at a faster rate than has ever been recorded. The dramatic increase in surface temperature is accelerating the melting of the Greenland and West Antarctic ice caps, which is likely to cause a more than five-metre rise in global sea levels over the coming centuries. This will cause low-lying coastal areas to flood, diminishing the amount of land available for our growing numbers to farm and live on.

Coastal regions are also being negatively affected by the increase in the use of artificial nitrogen-based fertilisers necessary for industrialised agriculture. As farmers inevitably use more of these chemicals than they actually need, any excess finds its way into waterways and heads for the shores. There it feeds plankton blooms, which can suffocate fish and shellfish, causing vast dead zones where coastal life cannot survive.

By studying all of these changes, scientists have gathered overwhelming evidence that they are being caused by human activity. Most graphs tracking such things as greenhouse gas concentrations, extinction rates and deforestation show a sudden steep climb

The rising urban population

How are the world's biggest megacities set to change in the next few decades?

Toyko, Japan

Delhi, India

Shanghai, China

Mumbai, India

São Paulo, Brazil

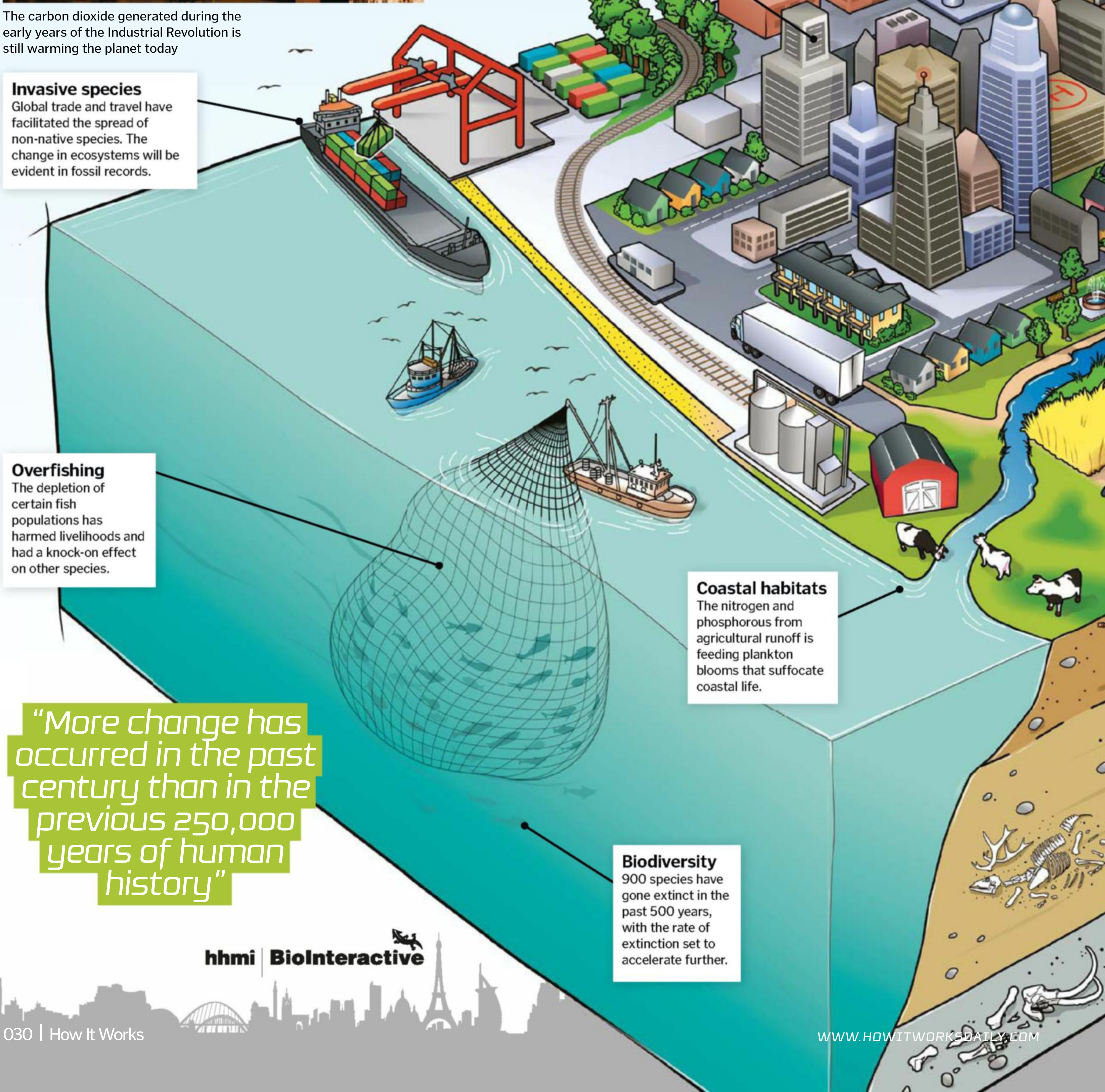
Beijing, China

Top city populations compared to London and New York

The carbon dioxide generated during the early years of the Industrial Revolution is still warming the planet today

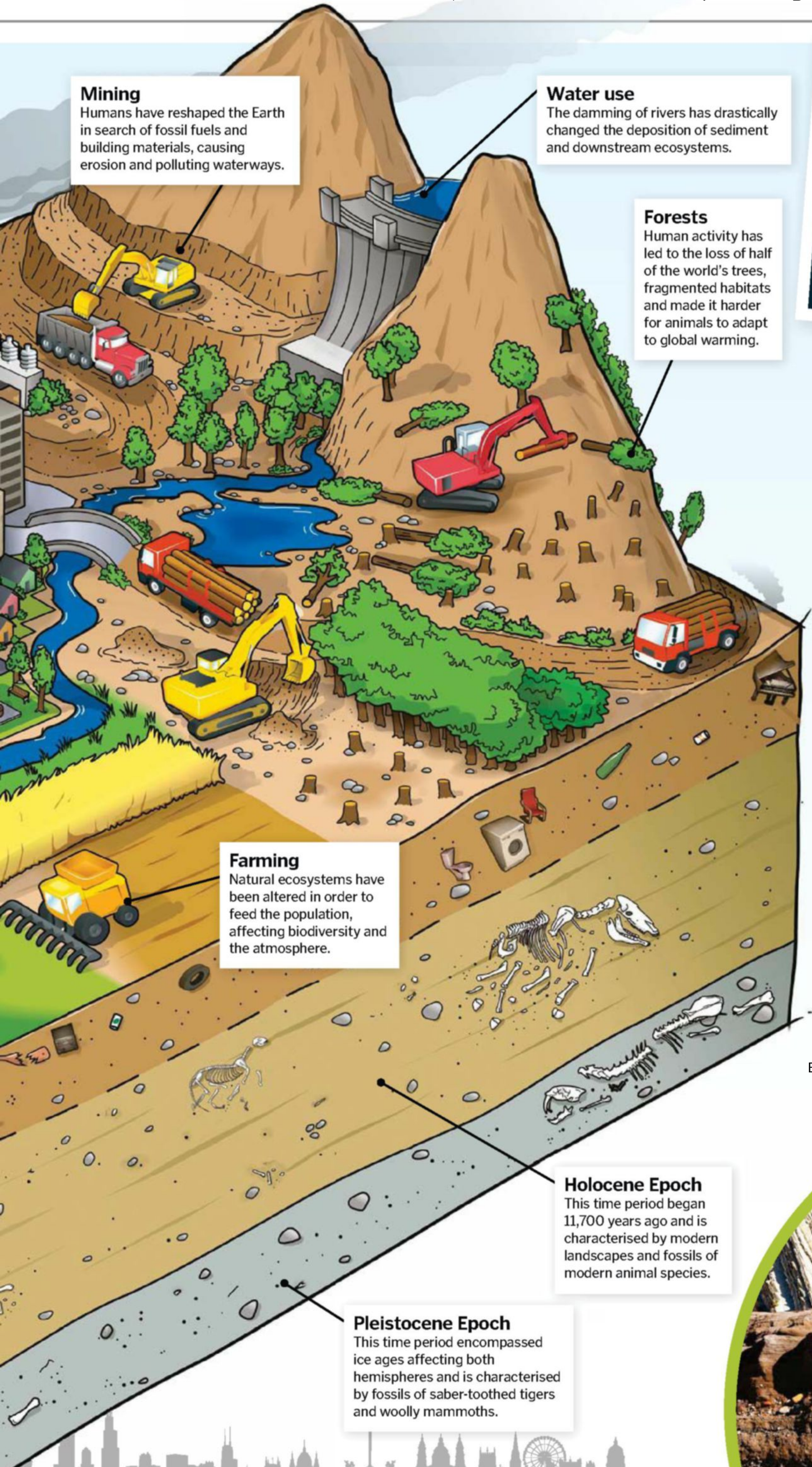
The human impact

What evidence might future geologists use to define the Anthropocene?



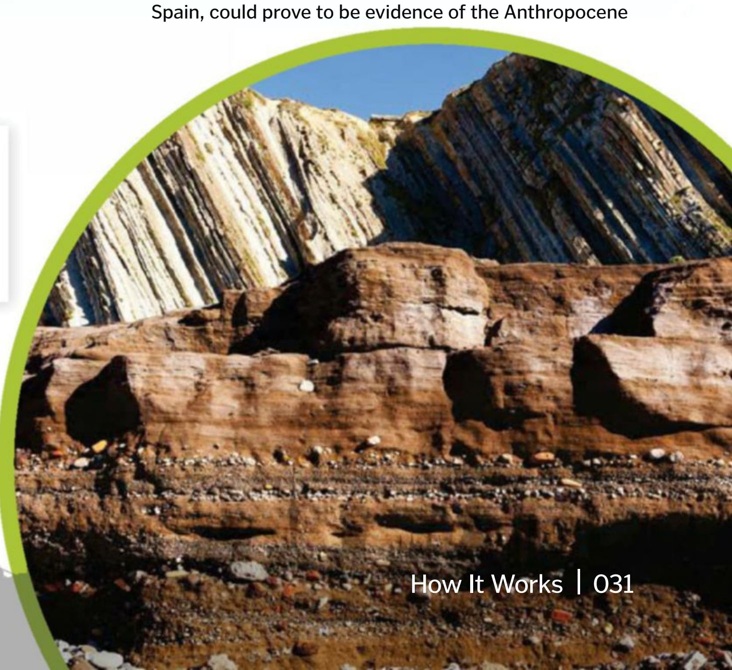
"More change has occurred in the past century than in the previous 250,000 years of human history"

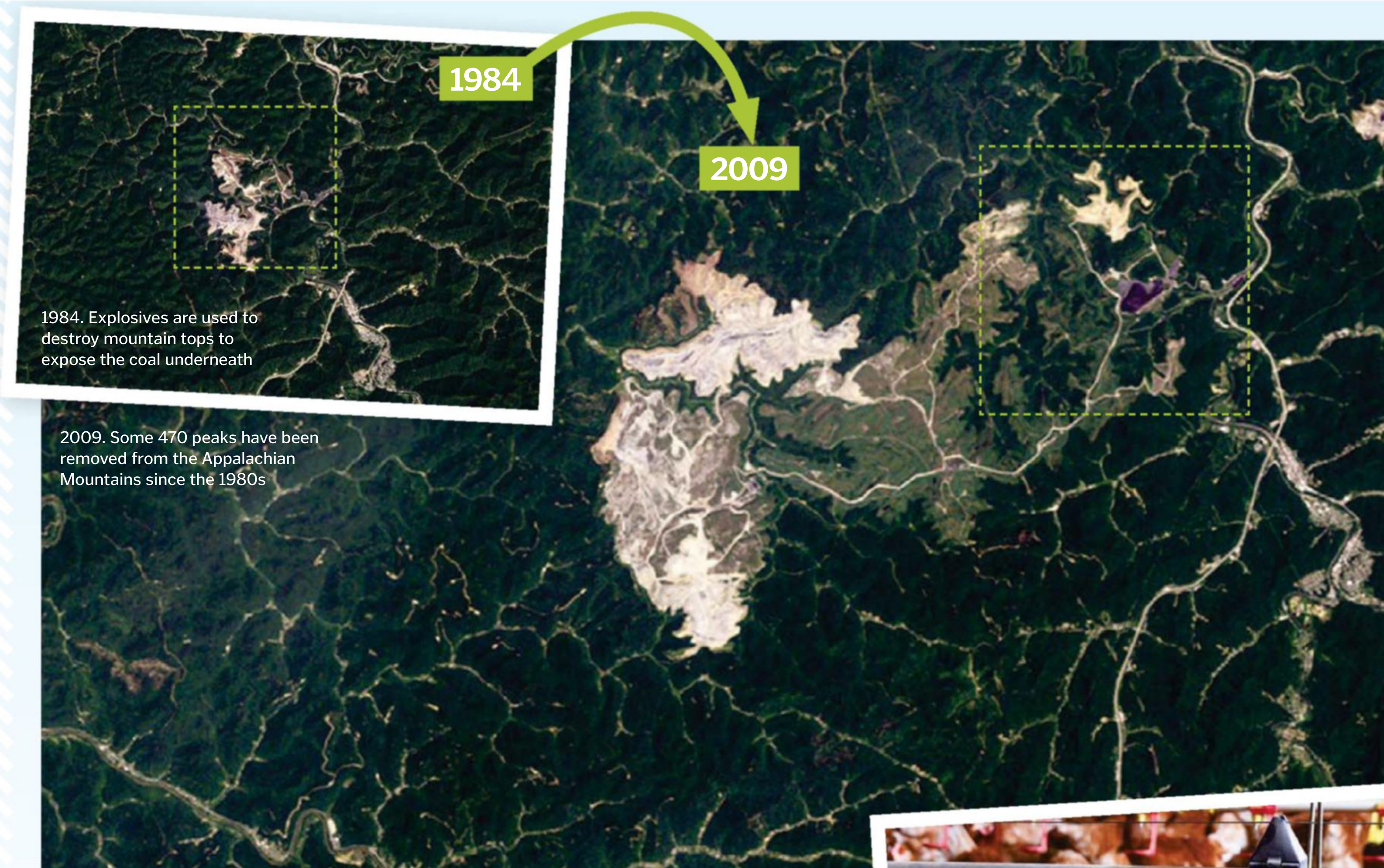
hhmi | BioInteractive



Just a few decades ago Dubai was mostly desert, but today it is one of the fastest-growing cities in the world

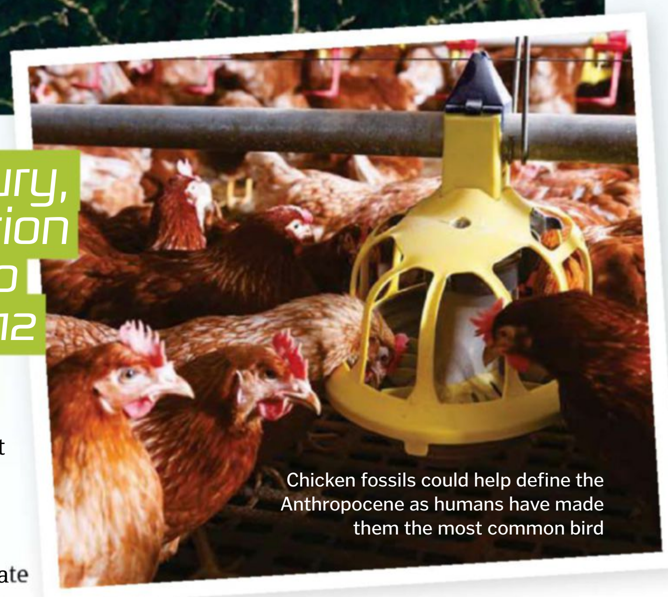
Below: a 7m layer of industrial sediment deposits in Biscay, Spain, could prove to be evidence of the Anthropocene





1984. Explosives are used to destroy mountain tops to expose the coal underneath

2009. Some 470 peaks have been removed from the Appalachian Mountains since the 1980s



Chicken fossils could help define the Anthropocene as humans have made them the most common bird

following the year 1950 when the Great Acceleration began. However, as history has shown us, these kinds of changes are not unprecedented. The climate, biodiversity and geology of the Earth have all been drastically altered before, creating conditions far hotter and colder than the current global average. So what is it that makes the shift into the Anthropocene any different?

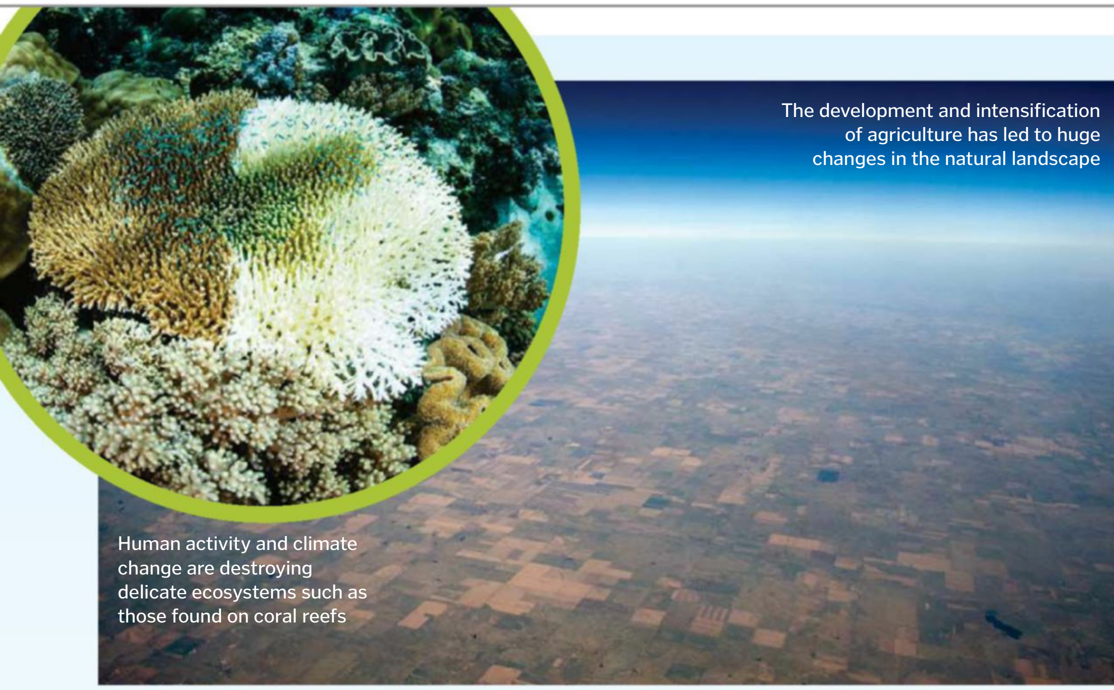
For the first time in the Earth's history, one species alone is causing all of these changes to the planet. And what's more, we know we are doing it. This is one reason why many geologists are so passionate about officially declaring the Anthropocene. Normally naming a new epoch is a matter of formality, but it is hoped that this time it could help to change people's view of the relationship between humans and the Earth.

By actively acknowledging that we are having such an enormous impact on the environment, we have the power to determine what its future will look like. At the moment, there are several possible scenarios that could play out, and it is up to us to decide which one to choose. Of course, we could simply carry on as we are, but that will only increase the likelihood of some pretty catastrophic events occurring. In the next century, the global population is set to grow to between 10 and 12 billion people, where it will hopefully level off due to declining birth rates. We are already struggling to provide 7 billion people with a decent standard of living, and so at our current rate of consumption, supporting even more is going to be a major challenge. Overpopulation could spark global conflicts and lead to a rise in instability, all of which would be made worse by the effects of global warming.

> "In the next century, the global population is set to grow to between 10 and 12 billion people"

The climate is already changing at an alarming speed, but providing enough fuel for 10 to 12 billion people will only accelerate these changes even more if we continue to use coal, oil and gas. The global average temperature has already increased by one degree Celsius since the late 1800s, and just one degree more would produce some drastic results. Environmental disasters such as floods, droughts and hurricanes would become more common, temperatures would soar to uninhabitable levels and rising sea levels would submerge more and more land underwater. Future geologists, if they still exist, would be able to study the relics of our cities in amazing detail as they would be buried in mud deposited by the rising waters. Plus, not only would we struggle to adapt to this warmer, wetter world, but most animal and plant species would also not be able to evolve fast enough to survive in their new habitats.

Another possible scenario would be to try to guide human society back to the simpler,



Human activity and climate change are destroying delicate ecosystems such as those found on coral reefs

The development and intensification of agriculture has led to huge changes in the natural landscape

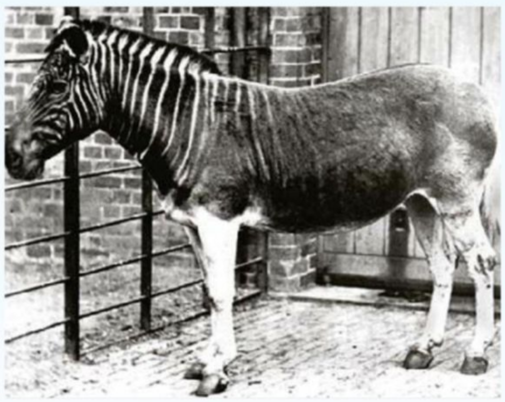
subsistence living of the 1800s. This would involve each family building their own home, making their own clothes and growing their own food. It would also mean harnessing all of our power from renewable sources such as the Sun and wind and giving up modern technologies including cars and the internet. Although this would certainly reduce our impact on the environment, it is likely to be both unrealistic and unpopular with the current population. For a start, there's seven times the number of people there were in the 1800s who would need to be supported by this lifestyle, and many have already grown attached to the luxuries of modern life.

Therefore, the most likely way we will reshape the future is by inventing new technologies and implementing new processes to solve the world's problems. The fact that we are becoming increasingly well-educated and interconnected can only help with this, and there are already signs that attitudes are beginning to change. Innovations in clean energy and the development of electric cars are helping to reduce our dependence on non-renewable fossil fuels, and in 2015, nearly 200 countries pledged to do their bit in helping to tackle climate change by adopting the Paris climate accord.

This agreement sets out to limit the increase in the global average temperature to well below two degrees Celsius above pre-industrial levels and provides incentives to cap the amount of greenhouse gas emitted by human activity. Meanwhile, the decline in biodiversity is being tackled by conservationists around the world who are working to restore depleted habitats and protect species on the brink of extinction.

Even though changes are already being made, there is still a lot of work to be done if we want to reverse the damage we have caused to the planet and secure a more stable future. If we can't reduce the risks then there may be only one solution: leave this planet in search of another. Space agencies and private companies are already beginning to explore the possibility of establishing human colonies on Mars, with the first manned mission to the Red Planet currently scheduled for the 2030s.

However, while we are still a long way off being able to make other worlds habitable, it makes sense to do everything we can to save the one we know can support us. Even though the gasses we have already pumped into the atmosphere will last for tens of thousands of years, it's not too late to intervene. Using our collective intelligence we can work together to come up with viable solutions for halting greenhouse gas emissions, removing existing gasses from the skies and reversing the damage caused to crucial habitats. If we are indeed living in the Anthropocene, then it's up to us to make it the era that humans change the planet for the better, rather than making it worse.



The quagga, a subspecies of zebra, is one of the many animals humans have driven to extinction

The human effect in numbers

208
new minerals have been formed solely or primarily due to human activity

Earth's population is predicted to reach
9.8 bn
by 2050 - an increase of over
32%
compared to today's numbers

Some studies suggest human activity is causing species to go extinct
1,000
times faster than would occur naturally

The global population only surpassed
1 billion
for the first time in the early
1800s

More than half the concrete ever used was produced in the past
20 years

Agricultural space takes up approximately
37.5%
of global land area

200+
scientific articles about the Anthopocene were published in 2016 alone

Pangolins

Find out why these scaly creatures continue to fascinate multiple cultures

Picture a pinecone with waddling legs, or imagine a moving artichoke, and you have the general appearance of a pangolin. These creatures are the only mammals in the world covered in scales. Though they seem similar to anteaters or armadillos, they are in fact more closely related to true carnivores such as cats, and they belong to their own order. Four pangolin species live in Asia, and another four inhabit Africa. You can tell them apart because the Asian ones have bristles between their scales.

The scales themselves are made of keratin, the same substance found in our fingernails. This armour offers strong protection. Pangolin comes from the Malay word *pengguling*, meaning 'something that rolls up', and that's precisely what they will do when in danger. Pangolins can roll themselves up into an almost impenetrable ball, and female pangolins will roll vulnerable young babies right up inside with them. The edges of the scales are very sharp. Pangolins can use them to slice off a finger or a predator's nose – anything that tries to go poking around in between them.

These animals are found in sandy areas of tropical and flooded forests, as well as savannas. Some pangolins live only on the ground, while others also spend time up in the trees. All are equipped to dig; using their stout front legs and strong claws to tunnel through the ground, kicking loose soil out vigorously behind them. During the day they mostly shelter from the sunlight; but although capable of digging their own burrows, pangolins prefer to occupy abandoned homes.

At night these solitary creatures go in search of insects. They have poor vision and hearing but a keen sense of smell. Once they have located a suitable meal, they tear apart termite mounds or excavate entire ant colonies. If they don't finish a meal in one sitting, they can patch up the hole and come back for the rest of the feast later.

Big cats become confounded when a pangolin rolls up; even lions can't bite through the scales

Wrap-around tail
Some pangolin species use their prehensile tails to help them climb trees and hang from branches.

Protecting pangolins

Like many animals, pangolins are affected by habitat loss, but the main danger they face is illegal poaching for human consumption and the use of their body parts in traditional medicines. Each year, tens of thousands of pangolins are killed to satisfy the need for bushmeat and the use of their scales in folk remedies. They are the most poached and trafficked mammals in the world.

In China and Vietnam, the flesh of pangolins is considered a delicacy, and the scales of pangolins have been used in Chinese medicines for hundreds of years. But with Asian pangolin populations plummeting, animal traffickers have begun to target African species to make up the difference, putting all of the species at significant risk.

There are many groups working to protect pangolins, including authorities and researchers. Yet the task is extremely difficult – the going rate for a pangolin has soared to over $200 (around £150) per kilogram, and an estimated 41,000-60,000 wild pangolins were taken in 2011 alone. An international trade ban on pangolins was established last year, but conservationists say that it is not being enforced strictly enough.

Many baby pangolins are left orphaned by human activity and require special care

Pangolin anatomy

What features set these armoured animals apart?

Pest control

Pangolins belong to a particular subset of animals that focus on eating insects. This type of creature, called an insectivore, is an important part of its ecosystem. A single pangolin can consume more than 70 million insects a year, mostly ants and termites, though they do supplement that diet on occasion with crickets, flies, worms and bee larvae.

Unlike most mammals, a pangolin cannot chew its food. Instead it swallows insects whole. To do this, a pangolin uses its very long tongue to probe inside trees and ground nests. The tongue is coated with a saliva that sticks to prey. The pangolin pulls its tongue back in, and special mouth muscles prevent insects from escaping once they've been guzzled.

A pangolin's tongue is covered with sticky mucus that comes from a large gland in its chest

Protective protein

Scales cover the pangolin's body from head to tail tip. They're made from the same protein as bears' claws.

Sticky tongue

An adhesive tongue longer than their body is what pangolins use to lap up their insect prey.

Grinding stones

Pangolins don't have teeth. To help digest food, they swallow pebbles – much like a chicken with its gizzard.

Curved claws

Large, tough claws enable pangolins to unearth ant and termite nests, or hollow out a burrow.

Face muscles

Strong muscles allow pangolins to voluntarily close their nostrils and ears when feeding. This protects against insect counterattacks.

Baby pangolins often get around by hitching a ride on their mother's long tail

"Pangolin comes from the Malay word pengguling, meaning 'something that rolls up"

The tallest tsunami wave

How an earthquake triggered a tsunami of epic proportions

Lituya Bay is an 11-kilometre-long T-shaped inlet on Alaska's southeast coast

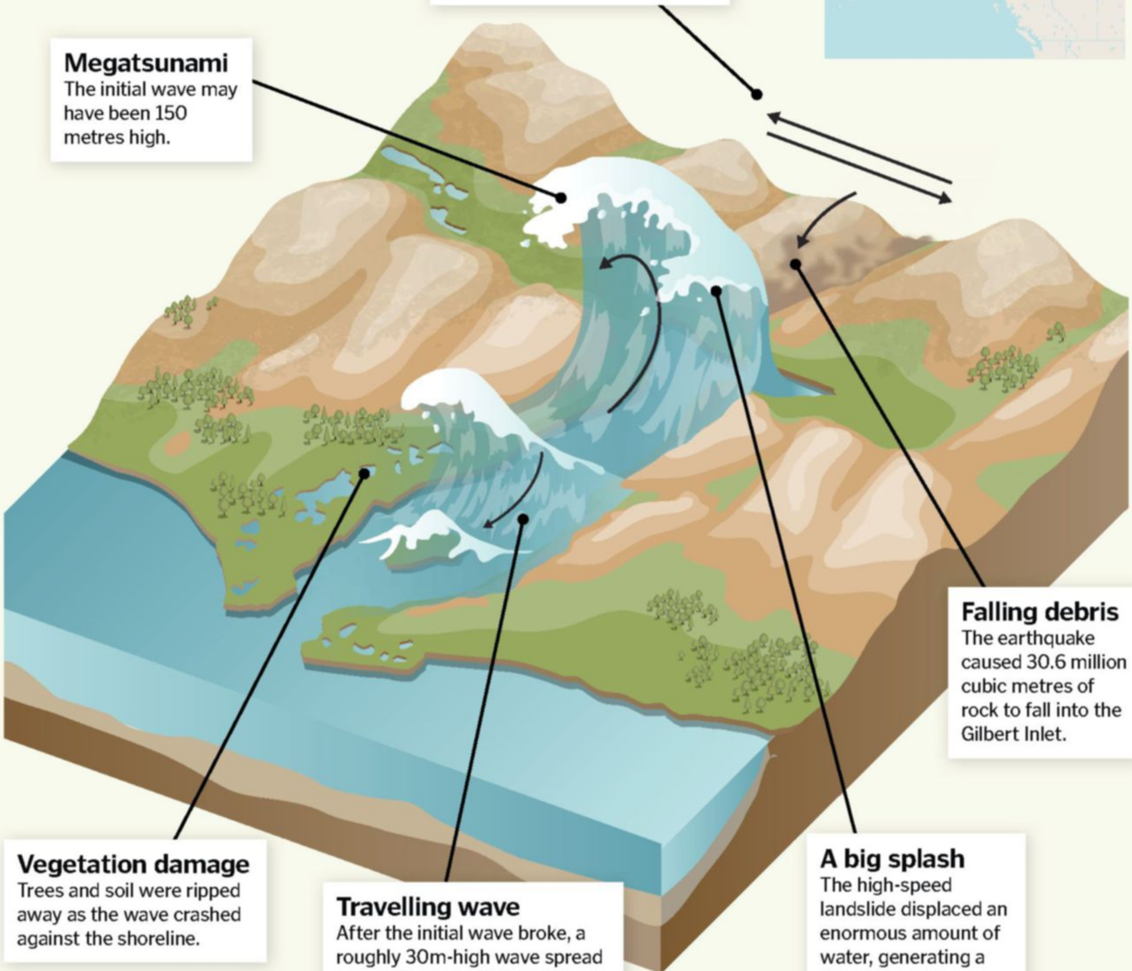
On the evening of 9 July 1958, fisherman anchored on Alaska's Lituya Bay felt their boats begin to shake violently as a powerful earthquake rumbled through the nearby mountains. Although their vessels survived the initial tremors, the worst was yet to come as they heard an enormous crash coming from the head of the bay.

Several million tons of rock had broken free from the mountains and slid down into the water at high speed. The impact was so forceful that a large air cavity was formed behind the debris, causing it to displace far more water than the volume of the landslide. The resulting megatsunami swept up the helpless boats, carrying them over the land and high above the trees, before washing them back into the bay or out to sea. As the wave crashed through the bay at speeds of around 160 kilometres per hour, the displaced water reached heights of 500 metres above the shoreline, stripping the bark from thousands of trees . Miraculously, several of the fishermen survived to tell their harrowing story.

The event itself wasn't unprecedented. Geologists had been studying the area for some time prior to the 1958 tsunami and discovered evidence of at least four similar waves dating back to 1854. The main clue was the band of younger trees situated below mature forests on the bay's shoreline, which suggested lower vegetation had previously been wiped out. This poses the question of when the next one will occur.

The 1958 megatsunami

What caused a terrifying wall of water to sweep through an Alaskan bay?



Terrible tremors
A magnitude 7.9 earthquake occurred along the Fairweather Fault, 21km from Lituya Bay.

Megatsunami
The initial wave may have been 150 metres high.

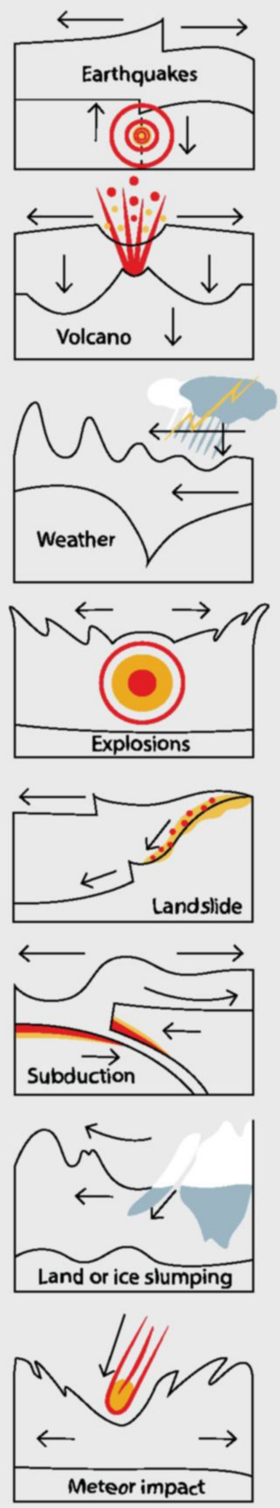
Falling debris
The earthquake caused 30.6 million cubic metres of rock to fall into the Gilbert Inlet.

Vegetation damage
Trees and soil were ripped away as the wave crashed against the shoreline.

Travelling wave
After the initial wave broke, a roughly 30m-high wave spread across the rest of Lituya Bay.

A big splash
The high-speed landslide displaced an enormous amount of water, generating a tsunami wave.

What causes tsunamis?



Volcano bird nests

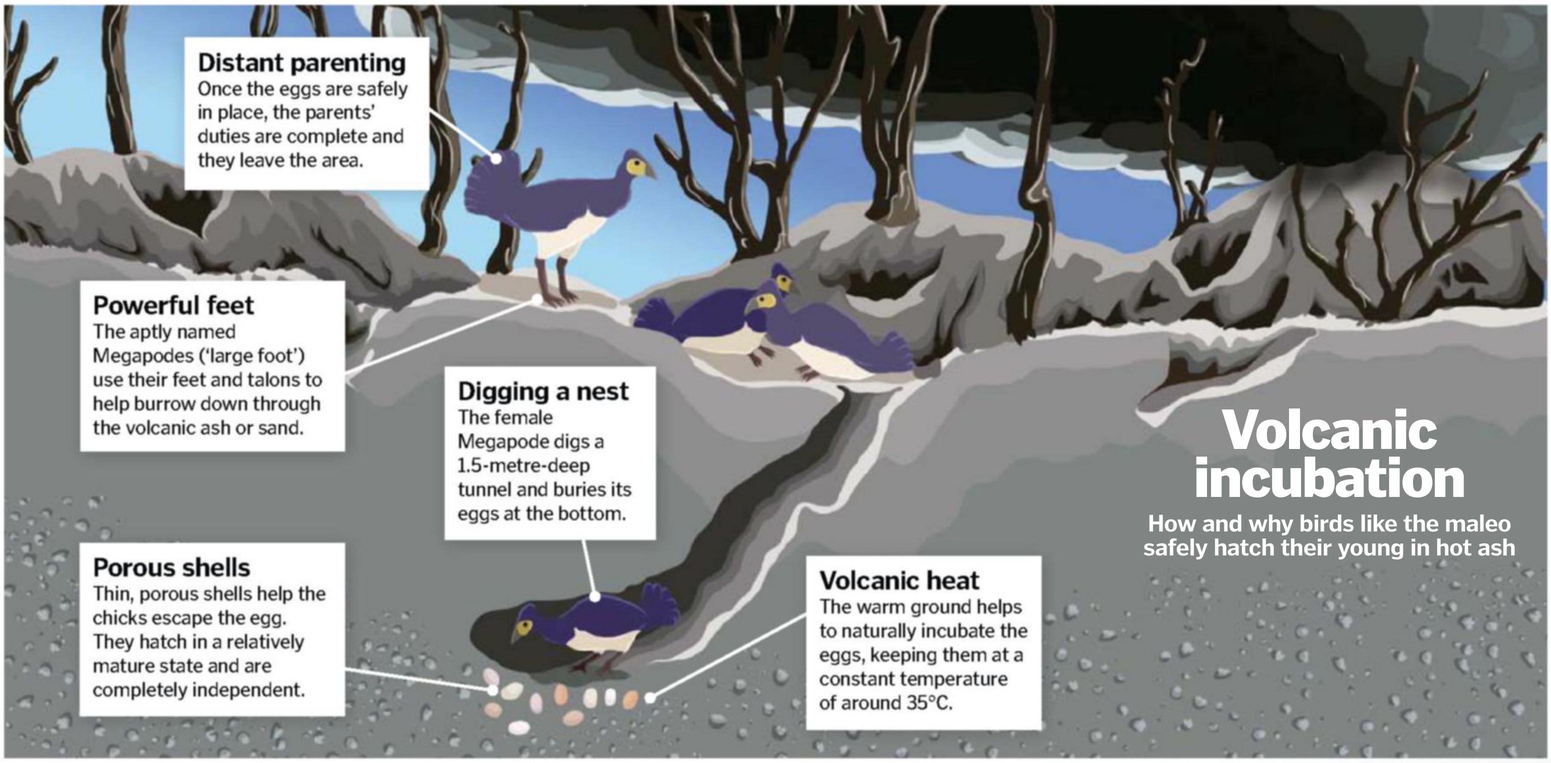
How the birds of the Megapode family use volcanic heat to incubate their young

It's easy to think of volcanoes as destructive forces of nature, but their activity can actually help to foster new life. Megapodes are a family of birds found around Australia and the Polynesian islands, and are unusual in that they do not incubate their eggs with their body heat.

Members of some species, such as the maleo in Indonesia, incubate their eggs in hot volcanic ash rather than building a typical nest. Using their large, strong feet, they dig holes in the ash and bury their eggs in the warm ground. This requires less energy than building and maintaining a nest and reduces the risk of parents being attacked as they sit on their eggs. Once the eggs are buried the parents will leave.

Megapodes are precocial, meaning they hatch in a relatively advanced state. As a result the newly hatched chicks are able to dig their way up to the surface and can fend for themselves remarkably quickly.

Unlike most other bird species, maleo hatchlings already have their feathers and can fly in a matter of hours



Leaning pines

Why do Cook pine trees always tilt towards to the equator?

If you ever get lost in a forest, look out for a Cook pine and you will quickly be able to tell which way is north or south. Native to the Pacific archipelago of New Caledonia, these tall evergreen trees have spread across tropical, subtropical and temperate regions around the world and can often be identified by their precarious tilt. What's even more interesting is that in a recent study of 256 Cook pines from five different continents, researchers found that those in the northern hemisphere lean southwards and those in the southern hemisphere lean towards the north. On average they tilt by 8.55 degrees, but the further away from the equator they grow, the greater the slant.

The reason they lean is likely phototropism, the behaviour found in most plants that causes them to lean towards the Sun. Most trees counteract this tilt with gravitropism – their sensitivity to the Earth's gravitational pull – but Cook pines seem to lack this ability. This could be due to their geographically restricted origins, which means they have to work harder to catch the angled sunlight at higher latitudes.

Cook pines were first classified during Captain James Cook's second mission to circumnavigate the globe

HOW SECURE IS YOUR DATA?

WHAT IS TARGETED ADVERTISING?

THE SCIENCE OF SOCIAL MEDIA

THE TECH BEHIND IT AND WHAT IT DOES TO YOUR BRAIN

Social media is one of the defining technologies of the 21st century, but what's really going on behind the scenes?

HOW DOES FACEBOOK MAKE MONEY?

DOES SOCIAL MEDIA AFFECT OUR HEALTH?

We don't seem to make more friends by spending time on social media

Does social media make us more friends?

On average, people have five social media accounts and spend an hour and a half checking them every day. It's billed as a way to make and strengthen connections with people, but, for all the social benefits, there is an argument that all of the time we spend online is taking away from the relationships that we make in the real world.

According to evolutionary anthropologist Robin Dunbar, we can only maintain up to 150 friendships at a time. This is known as the Dunbar Number, and it's based on the social groups that we evolved to live in; it's the size of most villages recorded in the *Domesday Book*, for example. Beyond that number, we can't maintain meaningful relationships because we don't have enough brain processing power or enough time to work on maintaining the connections.

Dunbar looked into social media friends in 2016 and found that, even though it feels like we have lots of friends online, these sites don't actually help us to be more connected. People had around the same number of close friendships online and offline.

How does Facebook make money?

In 2016, Facebook reported that over 1 billion people were signing into its site every day: that's one-seventh of the entire global population. The site is free, but all of those eyes scanning their newsfeeds are a captive audience for targeted advertising, and that's where Facebook makes its money; it shows us products and we click through and buy them.

On average, each user makes Facebook around \$3.50 (£2.70) every three months; in Europe it's \$4.50 (£3.50), and in the US and Canada that figure rises to over \$13 (£10). We give Facebook tons of personal data that can be used to predict what we might want to buy. Companies are willing to pay for this highly valuable information.

Other social sites also make money this way. Instagram and Snapchat utilise their photo-heavy formats to showcase brands, and Twitter offers promoted tweets and accounts, allowing companies to pay to get their content seen.

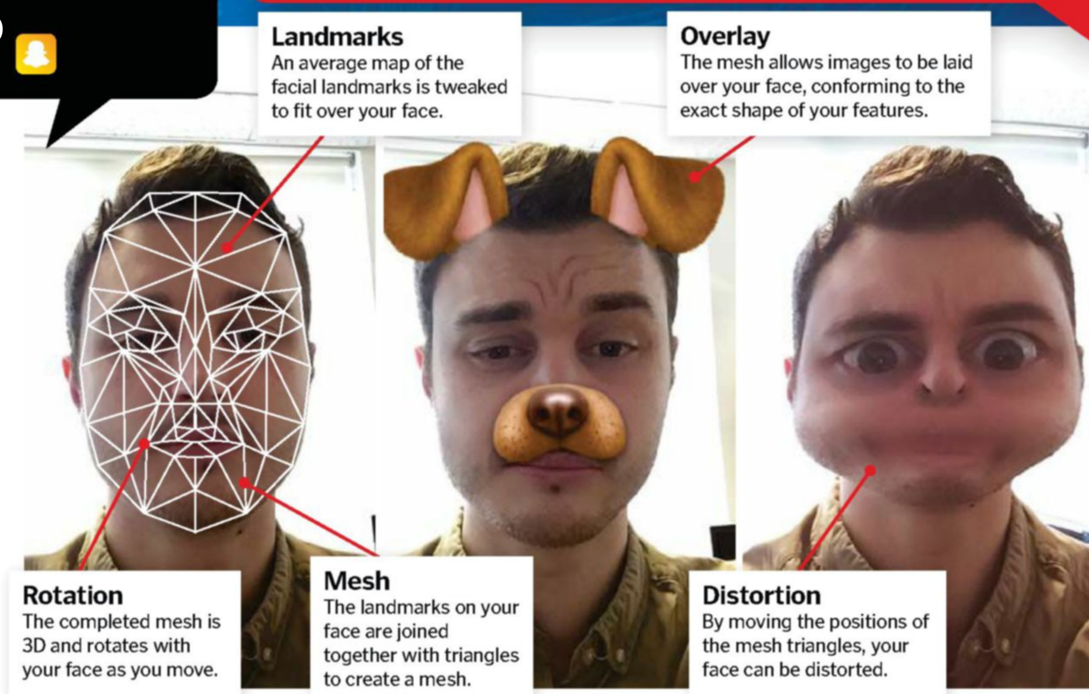
"On average, each user makes \$3.50 for Facebook every three months"

How do Snapchat filters work?

Selfie filters are based on the Viola Jones algorithm, which finds faces by scanning images for areas of light and dark, but Snapchat's Active Shape Model can see in even more detail.

The developers created a map of the average locations of key facial landmarks – like the edges of the eyes and lips – by manually marking their positions on dozens of photographs of real people. The points were then joined up to create a 3D model of a head.

In the Snapchat app, the average map is laid over your face and compared to your pixel data so that the points can be tweaked to fit your exact features. With your custom model completed, your face can then be textured and deformed.



Does social media affect our health?

Social media might seem light-hearted, but it has a darker side. In 2016, Childline delivered 12,000 counselling sessions related to online issues and cyberbullying, and a study of over 1,700 young adults by the University of Pittsburgh found that the more time people spend on social media, the more likely they are to be depressed.

In a UK survey of nearly 1,500 teenagers and young adults, researchers found that image-focused sites like Instagram and Snapchat performed the worst when it came to anxiety and mental wellbeing.

This doesn't necessarily mean that social media causes mental health problems – it could be that people spend more time on the sites when they are feeling down or anxious. On the other hand, social platforms can also be used to raise awareness of mental health and to help people find somebody they can talk to.

It's not all smiling selfies: social media use has been linked to depression and anxiety

The weakest link in cloud security is often your password

How secure is the Cloud?

It's easy to imagine that our data is secured somewhere up in the air, far out of the reach of prying eyes, but 'the Cloud' is actually a euphemism for giant server farms that hold your documents and images on their physical hard drives. When you upload your data to the Cloud, it's saved to these computers ready for you to download again when you need it next.

The first part of Cloud security is down to the provider; they need to make sure that their infrastructure is secure both digitally and physically. To do this they encrypt critical data, employ security personnel to protect their servers, and develop digital security systems that deter, detect and counter any attempts to access private files.

The second, and more vulnerable part of security is down to you. If people want your data they'll go for it through the easiest route, and this isn't usually by taking on the tech giants; it's much simpler to gain access to your passwords. The easiest way to secure your data is to make your codes stronger, change them often and guard yourself against phishing scams. It never hurts to make a backup of your files, too.

"People spend over an hour and a half on social media every day"

Social media stats

60bn messages are handled by Facebook Messenger and WhatsApp every day

31% of the human population have active social media accounts

176 million new social media users have joined in the last year

£11.50 The average annual worth of every user to Facebook

91% of retail brands use at least two social media channels

28,500m² Size of Facebook's giant server farm in Oregon

$27.64 billion Facebook's revenue in 2016

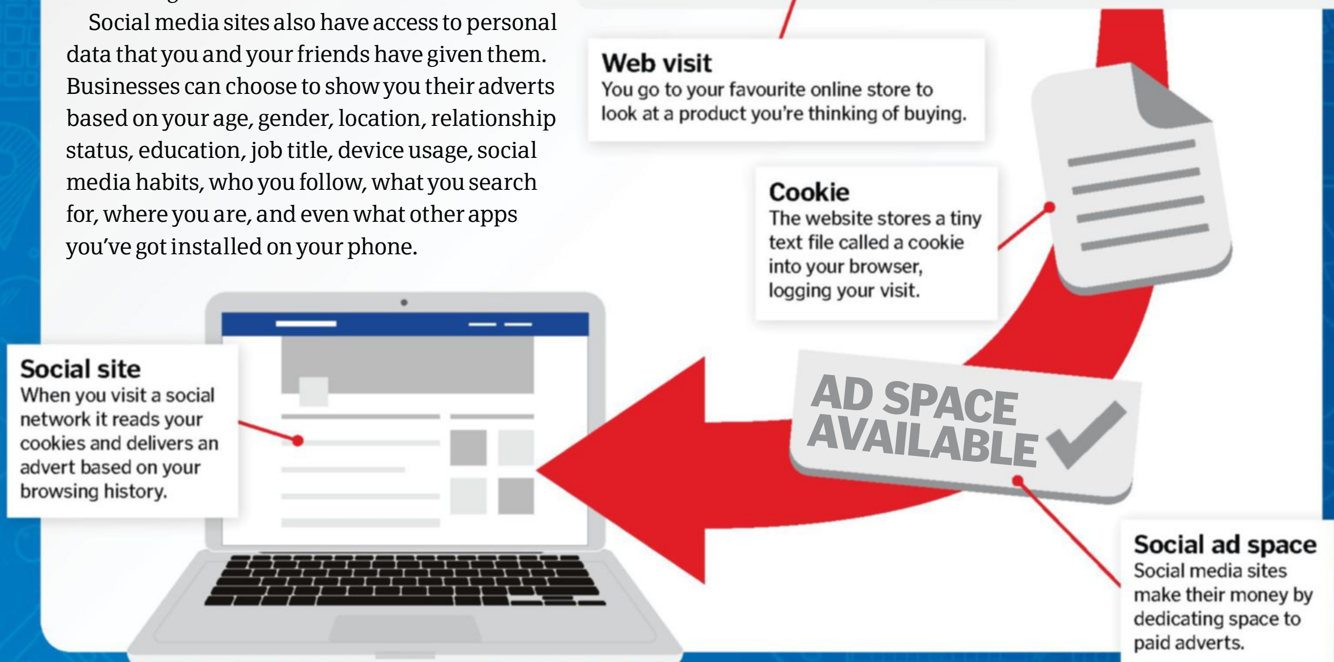
76 mins Average time spent watching video content on digital devices by US adults each day

DID YOU KNOW? *The first tweet was sent by Twitter founder, Jack Dorsey, in 2006. It simply said, "just setting up my twttr"*

How does targeted advertising work?

When you visit a website it saves a small text file called a cookie to your browser. Then, when you visit another website with advertising space, it looks through your cookies (known as your clickstream) and gives you a relevant advert. This is known as site retargeting, and it's just the tip of the iceberg.

Social media sites also have access to personal data that you and your friends have given them. Businesses can choose to show you their adverts based on your age, gender, location, relationship status, education, job title, device usage, social media habits, who you follow, what you search for, where you are, and even what other apps you've got installed on your phone.



Web visit
You go to your favourite online store to look at a product you're thinking of buying.

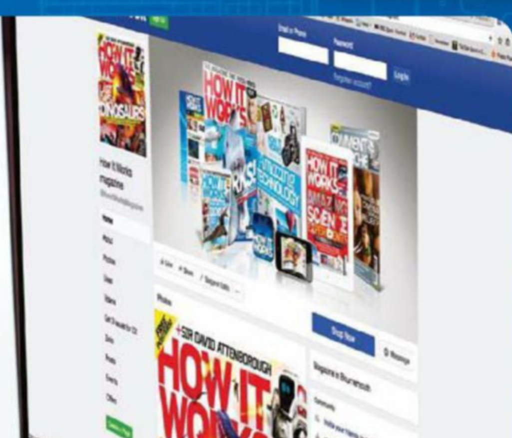
Cookie
The website stores a tiny text file called a cookie into your browser, logging your visit.

Social site
When you visit a social network it reads your cookies and delivers an advert based on your browsing history.

Social ad space
Social media sites make their money by dedicating space to paid adverts.

How does Facebook decide what to show in your newsfeed?

Facebook's news algorithm takes into account the kind of content you engage with most (i.e. photos or videos), your relationship with your friends, and how many likes or comments the post already has, then chooses what to show you. It is trained and tested by data scientists to help it pick the best posts.



THE MOST USED EMOJI

How do we express ourselves on different platforms?

#1

#2

#3

#4

#5

EMOJI FANS

A global study in 2016 revealed which countries' text messages have the highest proportion of emoji

France *19.8%*

Russia *10.9%*

US *9.2%*

Mexico *7.9%*

Turkey *5.8%*

Is social media addictive?

For some, social media becomes more than just a way to connect with friends; checking their feeds can turn into a compulsion and they become unable to control the amount of time spent on the internet.

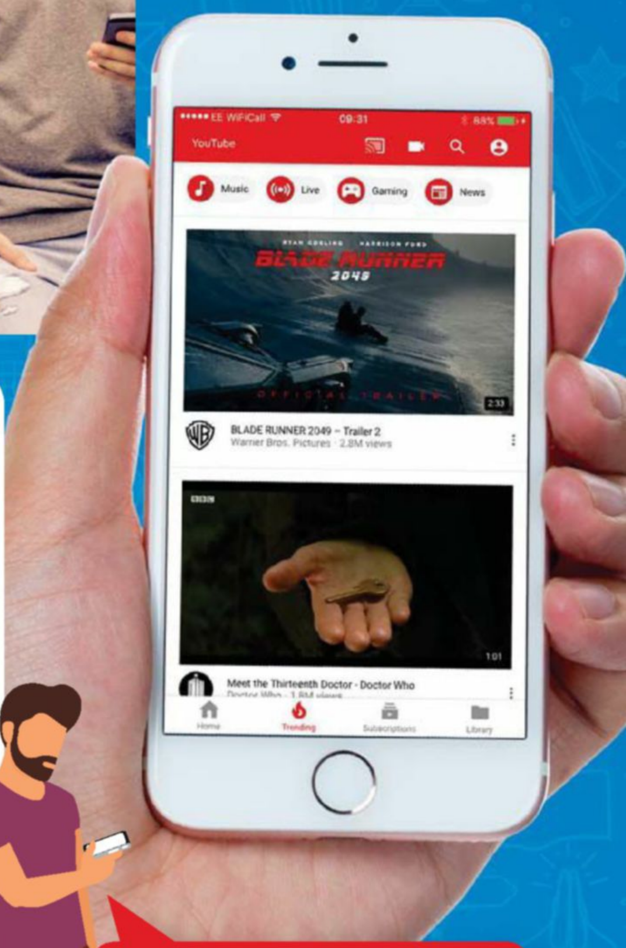
Internet addiction disorder, also known as problematic internet use or compulsive internet use, is unique to the 21st century, but it runs on biological impulses that have been around for millennia.

Our brains are wired to seek reward – it's what encouraged our ancestors to look for high-calorie sweet and fatty food, or to form lasting relationships with others – and it also drives addiction. The reward comes in the form of a chemical signal called dopamine, which is released in a part of the brain called the nucleus accumbens. Dopamine makes us feel good and drives us to repeat positive behaviours. However, some people can develop a tolerance to the dopamine rush, needing more and more to produce the same effect.

Social media can activate the reward centres in our brains

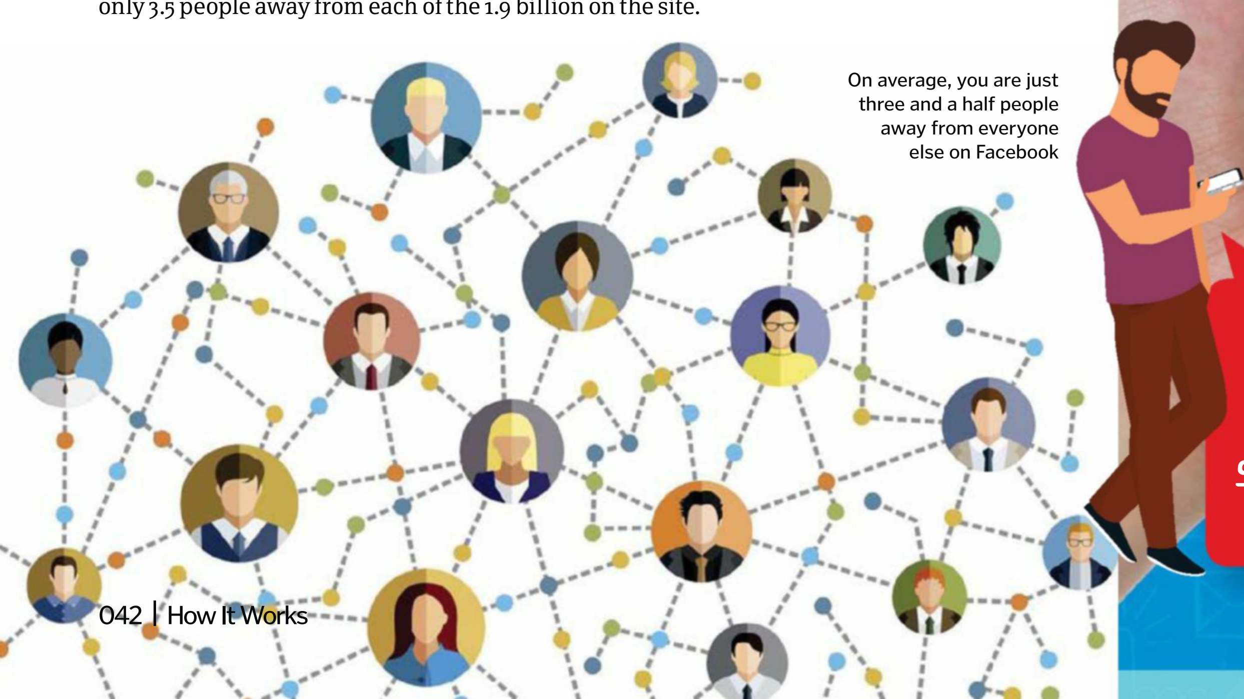
How does a meme go viral?

The word 'meme' was invented by scientist Richard Dawkins in 1976 to explain how ideas spread from person to person, replicating and mutating like genes. There isn't a formula for success, but researchers at the University of Memphis found that shorter memes, memes with swearing, and memes that could be reproduced quickly using a template were the most likely to do well.



What are the Facebook 'degrees of separation'?

In 2016, Facebook dug into their stats to find out how interconnected their active users really are. We've all heard of the six degrees of separation, but if you're active on this social network (i.e. you've logged in during the past 28 days) you're only 3.5 people away from each of the 1.9 billion on the site.



On average, you are just three and a half people away from everyone else on Facebook

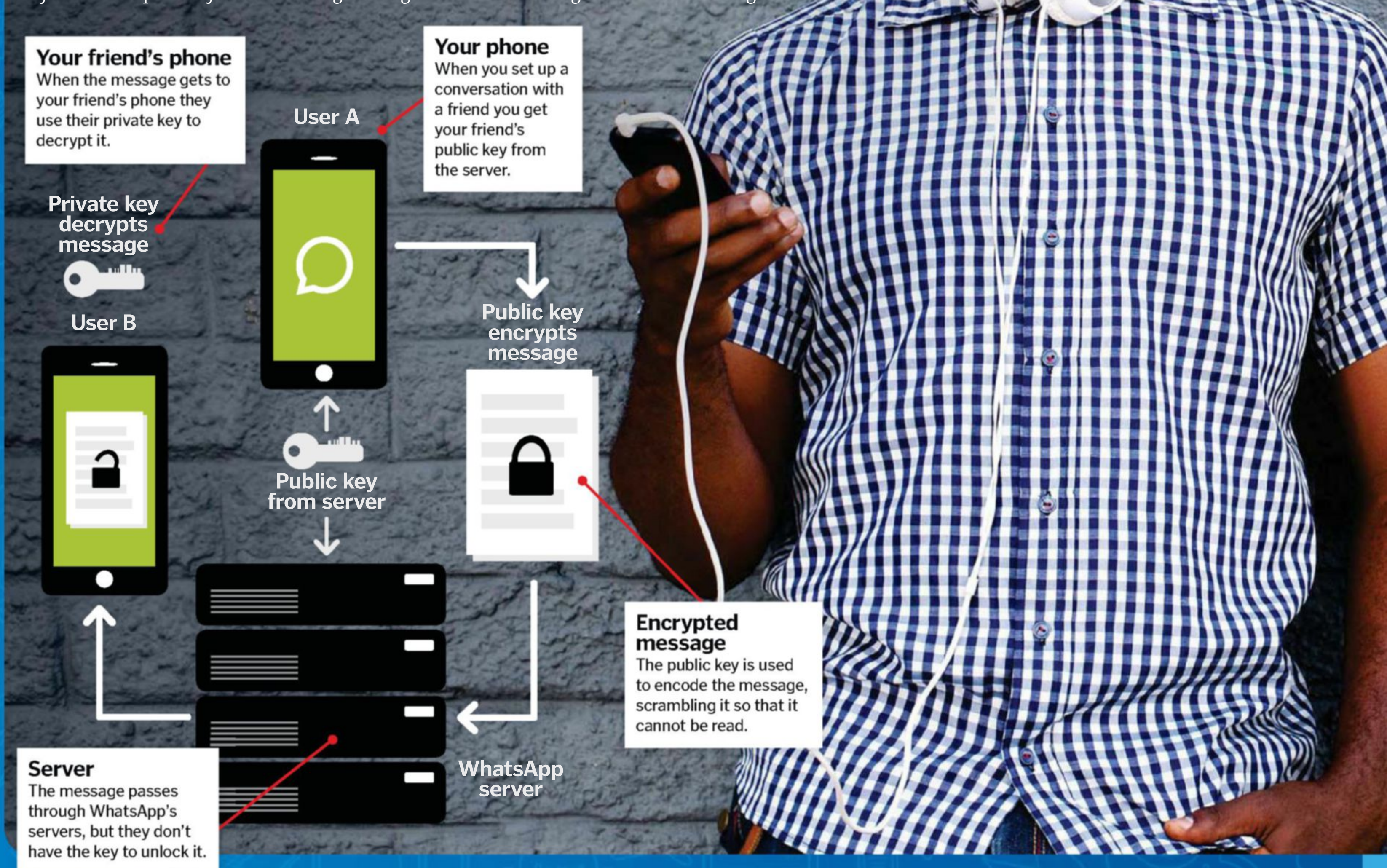
> "The word 'meme' was invented by scientist Richard Dawkins"

How does WhatsApp's end-to-end encryption work?

Since 2016, every message you send using WhatsApp has been end-to-end encrypted: this means that it can only be read by you and the recipient. It's based on something called the Signal Protocol.

When you start a chat it opens an encrypted session. This then calculates something called a 'master secret' using keys that are unique to you and the person you are sending messages to. The master secret is used to create a root key and a chain key, which in turn is used to make unique message keys for every message you send.

When you hit the send button the message is scrambled and locked with the key. When it reaches your friend's phone, they use their own private keys and the keys from the header of the message to unscramble it again.



Your friend's phone
When the message gets to your friend's phone they use their private key to decrypt it.

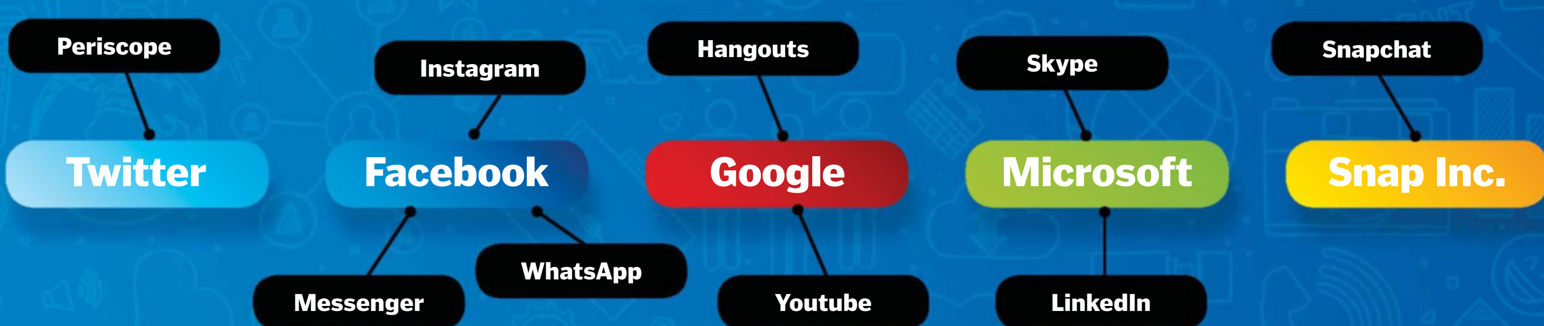
Your phone
When you set up a conversation with a friend you get your friend's public key from the server.

Encrypted message
The public key is used to encode the message, scrambling it so that it cannot be read.

Server
The message passes through WhatsApp's servers, but they don't have the key to unlock it.

Who owns what?

Several successful social media networks are now subsidiaries of other tech giants



Synthesisers

How these machines can recreate various instruments or create entirely new sounds

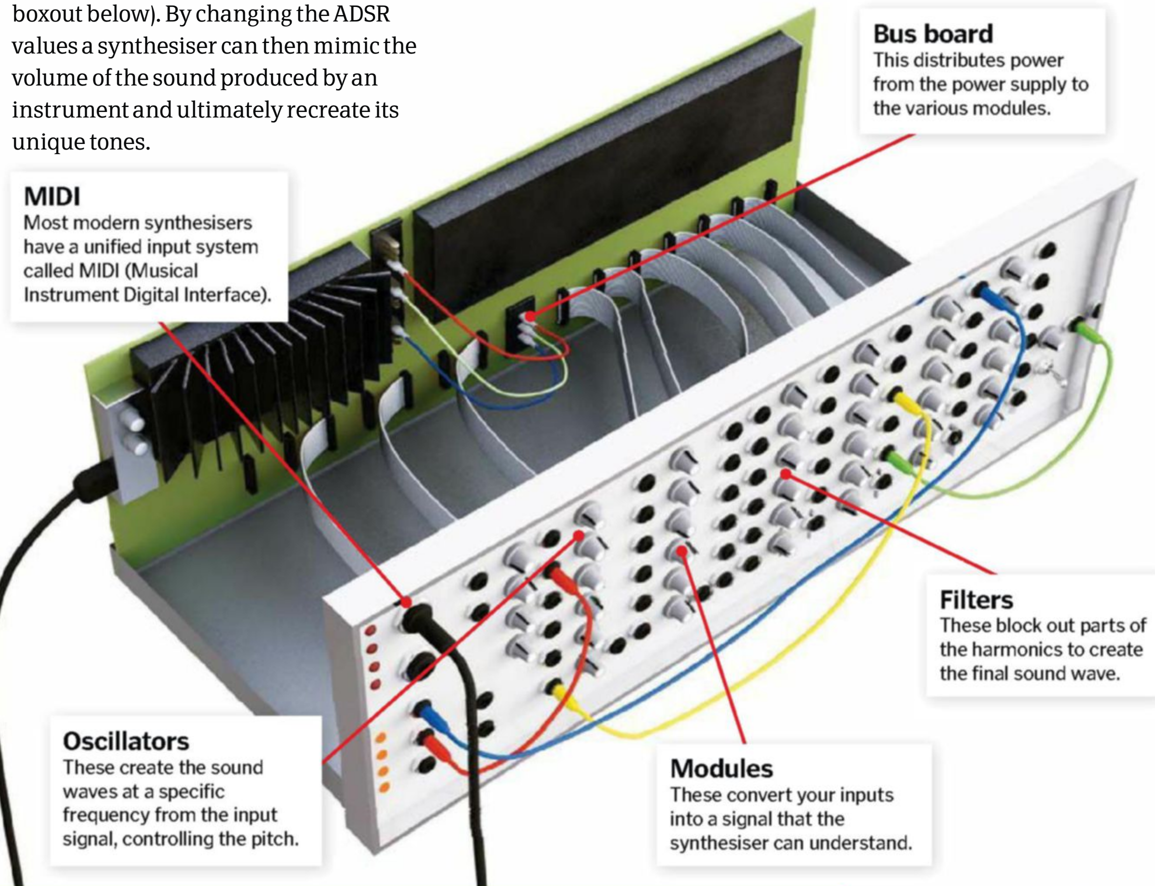
A synthesiser is a machine that can produce sound using a combination of oscillators, filters and amplifiers to change the type of sound you hear. It often comes in the form of a keyboard, with various keys and settings allowing you to copy other sounds, or create entirely new ones.

When a normal instrument creates a sound, it vibrates air particles and sends a wave of sound to your ear. These waves have a particular shape depending on the initial vibration and how the air is compressed and stretched out. Changing the frequency (the number of vibrations) and the amplitude (volume) will ultimately dictate what it sounds like, with the former dictating the pitch. By then also creating harmonics (related notes at different frequencies) an instrument can complete simple or complex sounds.

To recreate this, a synthesiser needs to recreate the waves themselves. It generates sound tones using oscillators, which can produce sounds with different waves and match them to a specific instrument. It can then also combine waves to create harmonics, and thereby make richer sounds. Some synthesisers begin with more complex sounds and then remove harmonics using filters to create the final sound. The waves also change in volume according to attack, decay, sustain and release (ADSR, see the boxout below). By changing the ADSR values a synthesiser can then mimic the volume of the sound produced by an instrument and ultimately recreate its unique tones.

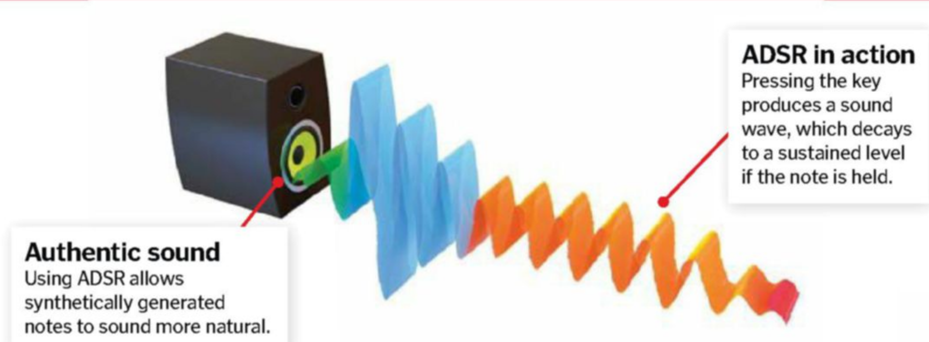
Modular synthesiser

How oscillators and filters are used to produce sound



ADSR

While sound waves have a particular shape and frequency, the volume or strength of the wave will also dictate the final sound. This is dictated by ADSR, or attack, decay, sustain and release. When a sound wave is first created, such as pulling a bow across a violin string, the tone jumps to its maximum volume, called the attack. As the note is held, it then drops slightly to a more regular level, called the decay. The note is then sustained at a volume until it stops being played. Like a bow being removed from the string, the sound then drops to nothing, which is called the release.



1 Attack

The key is pressed and the tone jumps

2 Decay

The key is held and the tone drops

3 Sustain

The key continues to be held and the tone is constant

4 Release

The key is released and the tone fades

HIW's top synth songs

Depeche Mode
I Just Can't Get Enough
1981

Human League
Don't You Want Me
1981

Eurythmics
Sweet Dreams
1983

Pet Shop Boys
West End Girls
1984

A-ha
Take On Me
1985

Light bulbs compared

Over time, a more energy-efficient bulb can save you money

KEY:
- Wattage to produce over 1,300 lumens
- Lifespan ● = 1,000 hours
- £ Average cost per bulb
- Ratio of useful (yellow) to wasted (pink) energy

Traditional incandescent

These bulbs heat a small filament of tungsten to produce light, with the filament glowing as a current is passed through it. This wastes a lot of energy, and the bulbs are relatively short-lived.

100 watts

£ 0.40

Halogen incandescent

These work similarly to a traditional incandescent bulb, but a halogen gas such as iodine is also used to prevent wear on the filament. This means it can grow brighter for a longer period of time.

70 watts

£ 1

Compact fluorescent

This type of bulb works by having excited gas in a compact fluorescent (CFL) tube emit ultraviolet photons. These cause the coating of the bulb to then emit visible light, and last quite a long time.

20 watts

£ 2

LED

LED bulbs are expensive, but they can last a long time thanks to the small semi-conductor units inside. When a voltage is applied, each of these units emits light.

18 watts

£ 8

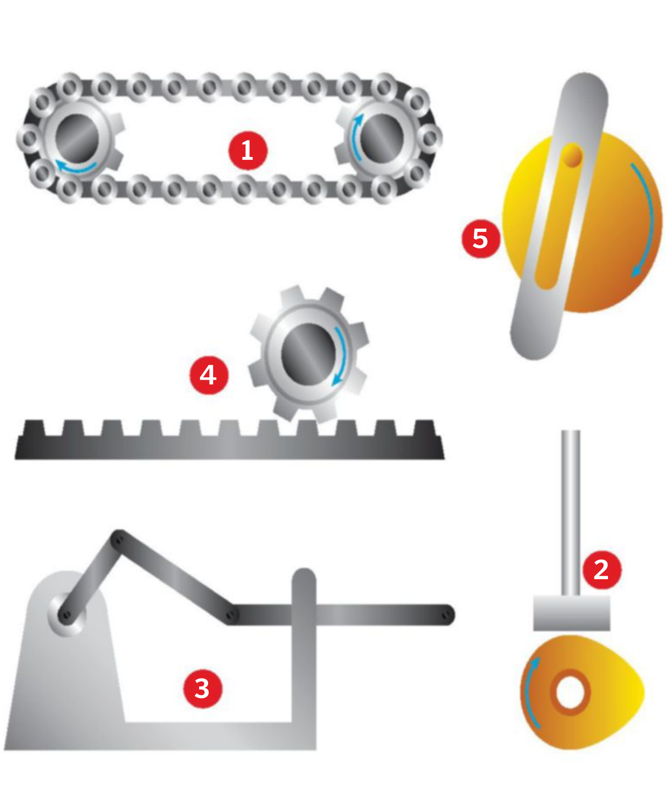
Converting motion

How we transfer motion from one form to another and why it's useful

You might not realise it, but you're probably converting motion in one form or another every day. Whether you're using tweezers, wheeling a wheelbarrow, or even just driving a car, it's a pretty regular part of our lives.

The point of converting motion is to make things easier to use. A wheelbarrow has handles, for example, to increase the torque between the force applied by your hands and the wheelbarrow itself. Tweezers, meanwhile, make use of levers so that the force you apply is reduced and more intricate objects can therefore be managed.

There are many different types of converting motion, from pulley systems to complex gears. Let's run through what a few are used for.



1. Chain and sprocket
Rotary motion into **linear motion**
Cars, bicycles, film projectors, printers.

2. Cam-and-follower
Rotary motion into **reciprocating motion**
Tumbler locks for keys, window locks.

3. Peg-and-slot
Rotary motion into **oscillating motion**
Roll-up windows, controlling valves, piston pumps.

4. Crank, link and slider
Rotary motion into **oscillating and reciprocating motion**
Engines, pencil sharpeners, fishing reels.

5. Rack-and-pinion
Rotary motion into **reciprocating motion**
Getting trains up steep slopes, steering.

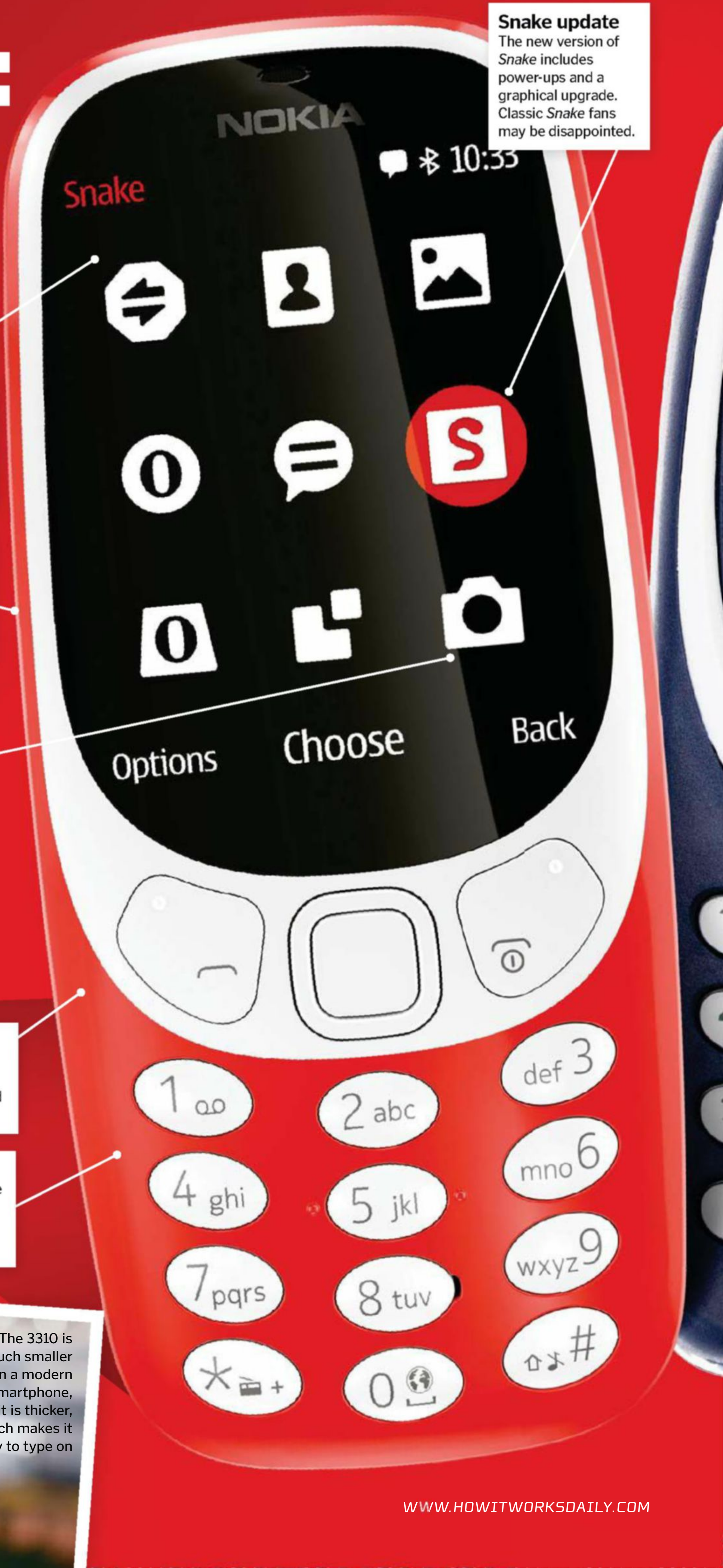
Nokia 3310: the old vs the new

How does the updated Nokia 3310 compare to the classic device?

The Nokia 3310 is one of the most famous mobile phones ever made. While it didn't pack in any truly revolutionary features, it got so many things right that, in the early 2000s, it was *the* phone to have. It included a whopping 84x48 pixel monochrome display and a diagonal direction control that let you move either up and down or left and right, plus one of the most addictive games ever created: *Snake*. It might not sound like much now in a world where smartphones have 4K displays, touch-screens and tens of thousands of games available to download with a tap, but back then it was fun, affordable, and it packed in a battery that lasted for weeks, not hours.

Fast-forward to 2017 and Nokia has decided to revisit it's fan-favourite and create a new model, packing in new technology but keeping the spirit of the old phone alive. There's no touch-screen and no app store, but there is an upgraded operating system, a colour display, and the same pleasing, pebble-like shape that feels so good in your hand. Oh, and it's got *Snake*. Take that, iPhone.

What's more, the new 3310 should last for around a month on standby. That's right – you can leave it switched on and 30 days later you'll still be able to pick it up and write a text using the 12-button keypad. With the new phone available now for under £50 (around $65), we thought we'd take a look at how far tech has come in the last 17 years by comparing the original 3310 to the new model.



Snake update
The new version of *Snake* includes power-ups and a graphical upgrade. Classic *Snake* fans may be disappointed.

Display
The original 3310 had a 1.5-in monochrome screen; the new model boasts a 2.4-in colour display at 167 pixels per inch.

Blowout battery
The new 3310's battery should last up to an incredible 744 hours on standby. The original 3310 only lasted 55 - 260 hours.

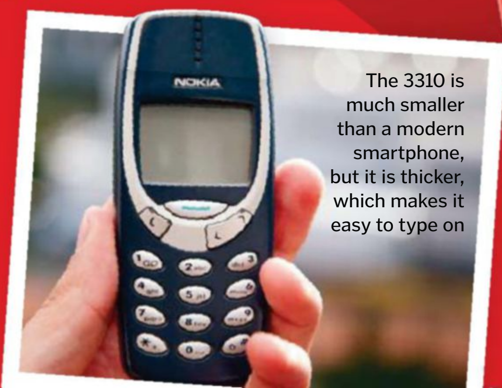
2MP camera
The original 3310 came before phones featured cameras. The new one only sports a measly 2MP lens, which is nothing special.

Comparing the 3310s

How does the old model measure up to the new?

FM radio & MP3
The new model of the phone packs in an FM radio and MP3 player, along with microSD card storage for all your tracks.

Dual-SIM
The new 3310 allows you to use two SIM cards and switch between them so you can always use the one you need.



The 3310 is much smaller than a modern smartphone, but it is thicker, which makes it easy to type on

DID YOU KNOW? *The keypad on the original 3310 could be removed for cleaning, so you could fix broken buttons in seconds!*

The original Nokia 3310 was a huge commercial success, selling 126 million units worldwide

Weight
The new Nokia is far lighter than the original thanks to the advance of tech. It weighs just 79.6g, compared to the original's 133g.

Classic design
One of the best things about the 3310 was that it was so comfortable to hold in your hand. The new model tries to recreate that.

Diagonal control
There were only two arrow keys on the original 3310, but because they were diagonally placed you could scroll up and down or left and right.

Storage
The original 3310 had limited storage – contacts were stored on the SIM and only eight recent calls were listed.

"The new model packs in new tech but keeps the spirit of the old phone alive"

Customisable
The case of the 3310 was removable, so you could customise your phone with new covers and designs whenever you wanted.

Price
When the first 3310 launched back in 2000 it cost around £130. Components are cheaper now, so the new model is just £49.99.

Retro features we still want

Flip phones
Flip phones were really cool. You could flick open to answer a call, snap it shut when you were done, and best of all, the phone fitted neatly into a pocket. Bring them back!

Keyboards
Blackberry was the real star when it came to keyboards on phones. Yes, it's a bit fiddly, but it means with practice you can literally type with your eyes closed.

Comfort
The thing we really miss in the modern age of flat smartphones is a phone design that's really comfortable to hold. Bring back round, pebble-like designs we say!

Gas flares

How industrial plants get rid of unwanted gases

Gas flares are large plumes of fire that are used in industrial plants as a safety procedure. They are used in the drilling of natural gas and oil, but how a gas flare is utilised for each varies a bit.

When drilling for oil, the stored oil can also contain large amounts of natural gas. Although valuable it cannot always be stored for use. So, in these cases, a temporary flare is used to relieve pressure and make the liquids and gas stable. The gas is transferred into a flare stack in the refinery – a large vertical column – and ignited. A flare then fires out from the top as the gas is burned, which can last for weeks.

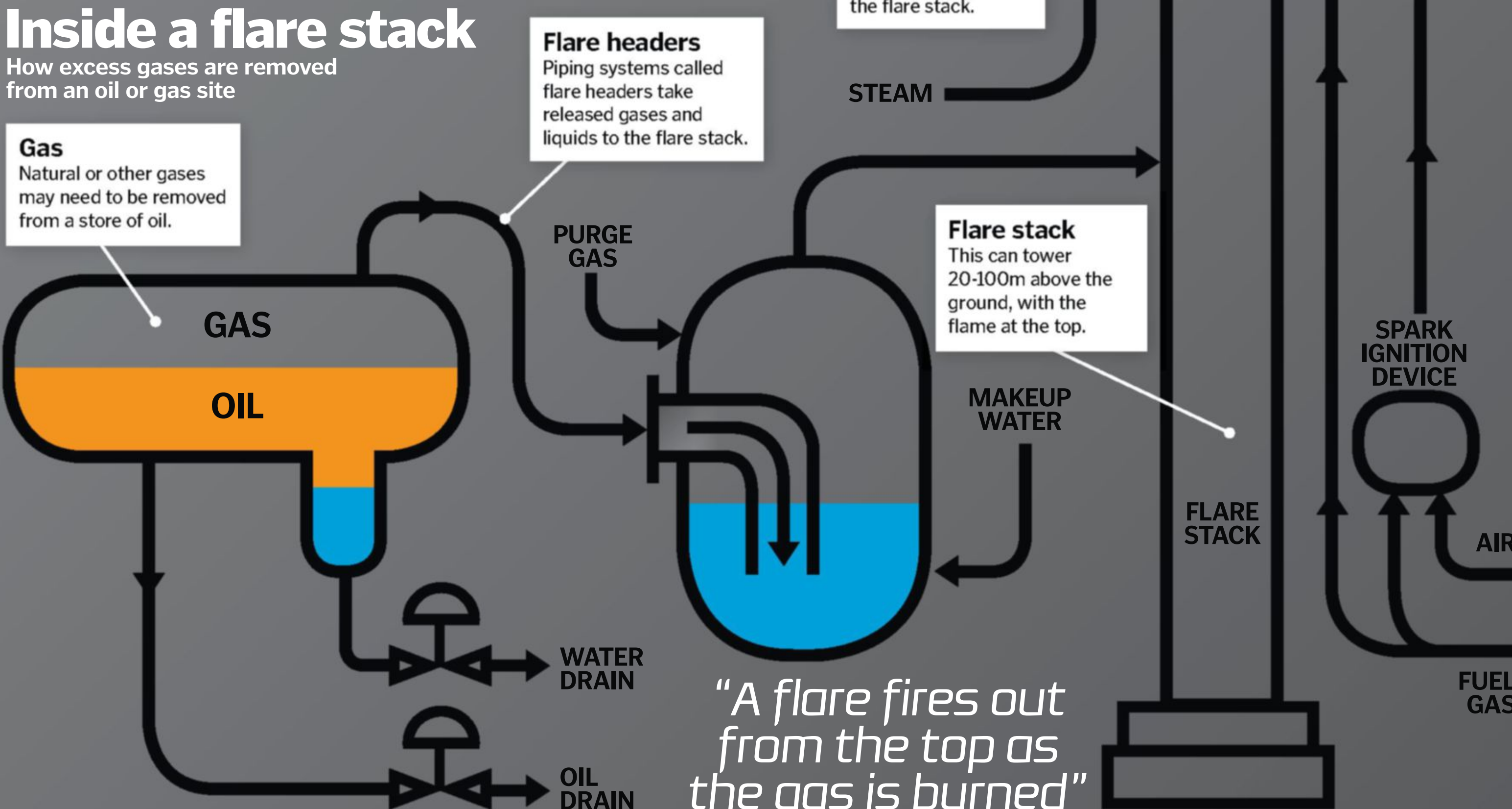
At gas processing plants, gas flares have a different function. Here they are used as a fail-safe to prevent the build-up of gases. If piping becomes over-pressured, the waste gas is released into the flare stack and ignited, lowering the risk of a fire or explosion.

Although they might seem wasteful, gas flares are somewhat environmentally friendly, as they burn some gases that would be hazardous at ground-level at a higher altitude. Some of these include sulphur dioxide, hydrogen sulphide and nitric oxide, all of which are burned into less harmful gases.

Gas flares make industrial plants safer and reduce the risk of explosions

Inside a flare stack

How excess gases are removed from an oil or gas site



"A flare fires out from the top as the gas is burned"

THE KUIPER BELT

WILDLIFE OF A SHIPWRECK


LOSE YOURSELF IN A WORLD OF
Vinyl
FIND YOURSELF IN
OXFAM'S ONLINE SHOP
oxfam.org.uk/shop
TIME ON MY HANDS
COLUMBIA
OXFAM

Detecting life on Earth

To find life on other planets, we may need to study our own

Finding life on other worlds is one of the great endeavours of our time. We've found dozens of planets beyond our Solar System that could support life, not to mention the myriad of worlds that orbit our Sun. But how we detect life on one of these worlds has been a bit of a head scratcher. Could Earth hold the key?

The problem stems from what to look for. In our own Solar System we can look at the surface and study the atmosphere and emissions from various enticing worlds. These include the moons Enceladus and Titan, and Mars of course, too. As for exoplanets, a new suite of telescopes will shortly come online that could help us study their atmospheres. Even once we can do all this, though, we need to know what to look for.

In 1990, the late astronomer Carl Sagan devised an experiment. As the Galileo spacecraft flew past Earth, to gain speed on its journey to Jupiter, it trained its instruments on our own planet. Sagan and his co-authors used this data to try and work out if they could detect life on Earth. The answer? Yes, with a pretty high degree of accuracy. They published their findings in a paper in 1993.

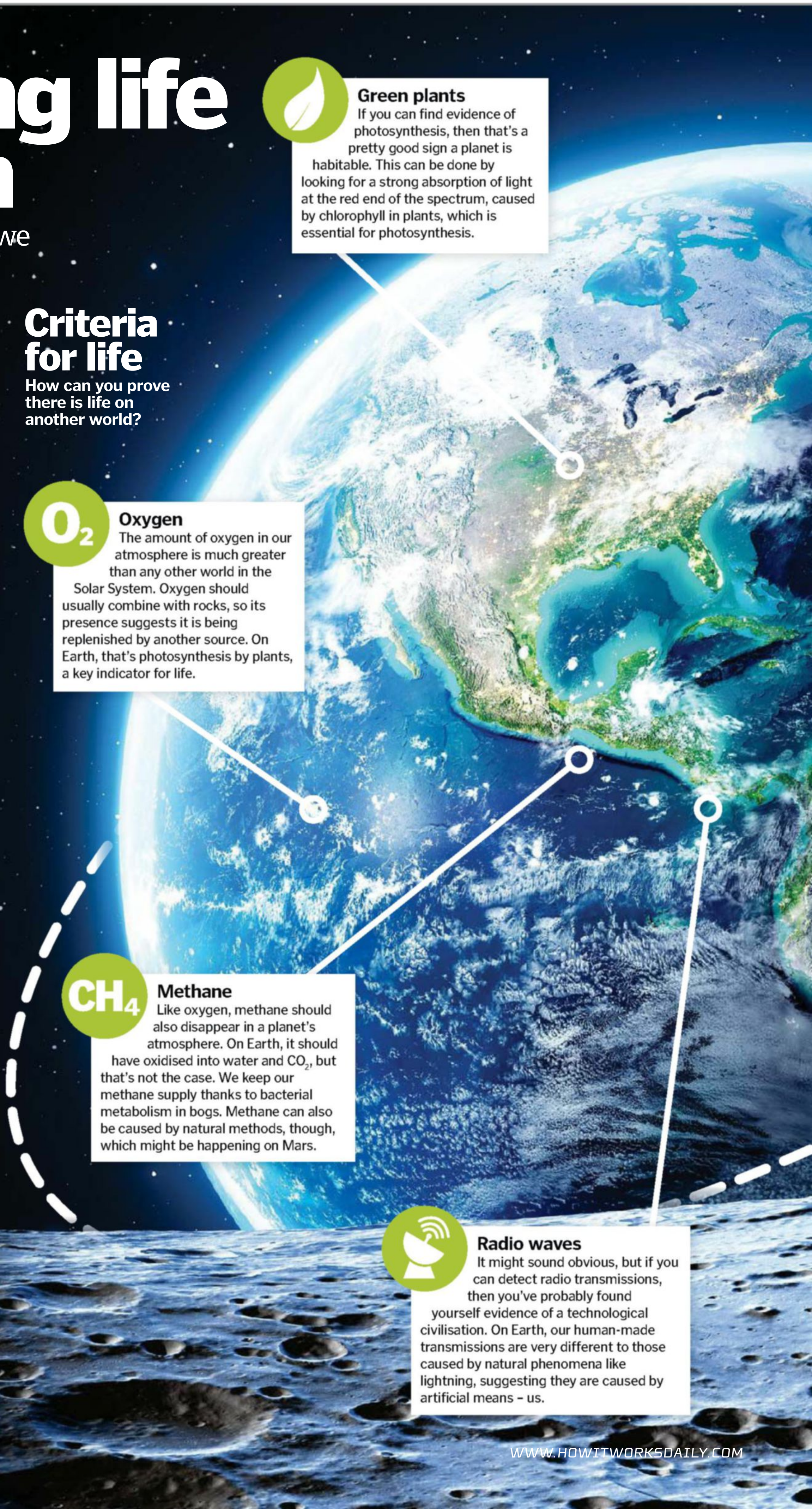
To confirm their findings they used a later flyby of the Moon in 1992. They used data from this flyby to confirm that the Moon indeed appeared lifeless. However, they ran into a problem with organic compounds called porphyrins, found in lunar soil. Although a possible biosignature, these were undoubtedly created by nothing to do with life at all.

This inspired a now famous doctrine for finding life known as the Sagan criteria. There were four different pieces of evidence that would need to be found together in order to say beyond reasonable doubt that life existed on a planet. For Earth, it was a no-brainer that life was abundant here.

Whether this same technique can one day be applied to other worlds remains to be seen, as we are only now refining our methods. But we will undoubtedly have Earth to thank if a discovery of life is made elsewhere.

Criteria for life

How can you prove there is life on another world?



Green plants

If you can find evidence of photosynthesis, then that's a pretty good sign a planet is habitable. This can be done by looking for a strong absorption of light at the red end of the spectrum, caused by chlorophyll in plants, which is essential for photosynthesis.

O_2 Oxygen

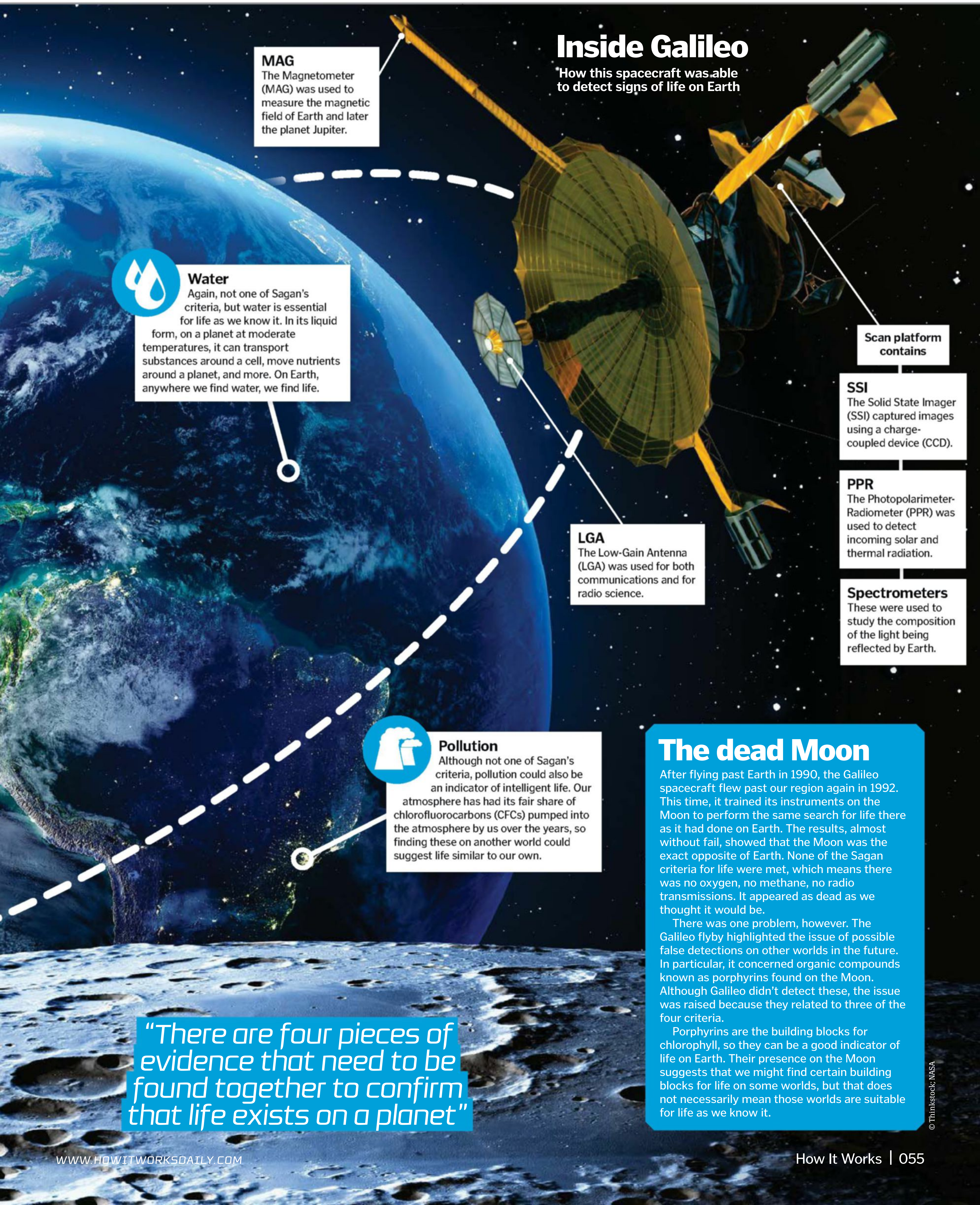
The amount of oxygen in our atmosphere is much greater than any other world in the Solar System. Oxygen should usually combine with rocks, so its presence suggests it is being replenished by another source. On Earth, that's photosynthesis by plants, a key indicator for life.

CH_4 Methane

Like oxygen, methane should also disappear in a planet's atmosphere. On Earth, it should have oxidised into water and CO_2, but that's not the case. We keep our methane supply thanks to bacterial metabolism in bogs. Methane can also be caused by natural methods, though, which might be happening on Mars.

Radio waves

It might sound obvious, but if you can detect radio transmissions, then you've probably found yourself evidence of a technological civilisation. On Earth, our human-made transmissions are very different to those caused by natural phenomena like lightning, suggesting they are caused by artificial means – us.



Inside Galileo

How this spacecraft was able to detect signs of life on Earth

MAG
The Magnetometer (MAG) was used to measure the magnetic field of Earth and later the planet Jupiter.

Water
Again, not one of Sagan's criteria, but water is essential for life as we know it. In its liquid form, on a planet at moderate temperatures, it can transport substances around a cell, move nutrients around a planet, and more. On Earth, anywhere we find water, we find life.

LGA
The Low-Gain Antenna (LGA) was used for both communications and for radio science.

Scan platform contains

SSI
The Solid State Imager (SSI) captured images using a charge-coupled device (CCD).

PPR
The Photopolarimeter-Radiometer (PPR) was used to detect incoming solar and thermal radiation.

Spectrometers
These were used to study the composition of the light being reflected by Earth.

Pollution
Although not one of Sagan's criteria, pollution could also be an indicator of intelligent life. Our atmosphere has had its fair share of chlorofluorocarbons (CFCs) pumped into the atmosphere by us over the years, so finding these on another world could suggest life similar to our own.

"There are four pieces of evidence that need to be found together to confirm that life exists on a planet"

The dead Moon

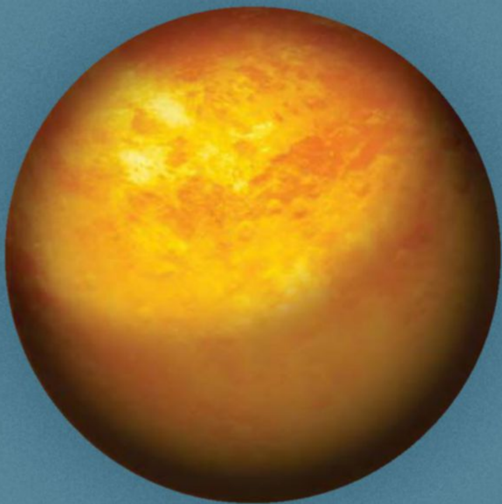
After flying past Earth in 1990, the Galileo spacecraft flew past our region again in 1992. This time, it trained its instruments on the Moon to perform the same search for life there as it had done on Earth. The results, almost without fail, showed that the Moon was the exact opposite of Earth. None of the Sagan criteria for life were met, which means there was no oxygen, no methane, no radio transmissions. It appeared as dead as we thought it would be.

There was one problem, however. The Galileo flyby highlighted the issue of possible false detections on other worlds in the future. In particular, it concerned organic compounds known as porphyrins found on the Moon. Although Galileo didn't detect these, the issue was raised because they related to three of the four criteria.

Porphyrins are the building blocks for chlorophyll, so they can be a good indicator of life on Earth. Their presence on the Moon suggests that we might find certain building blocks for life on some worlds, but that does not necessarily mean those worlds are suitable for life as we know it.

Candidates for life

Discover some of the worlds that fit aspects of the Sagan criteria

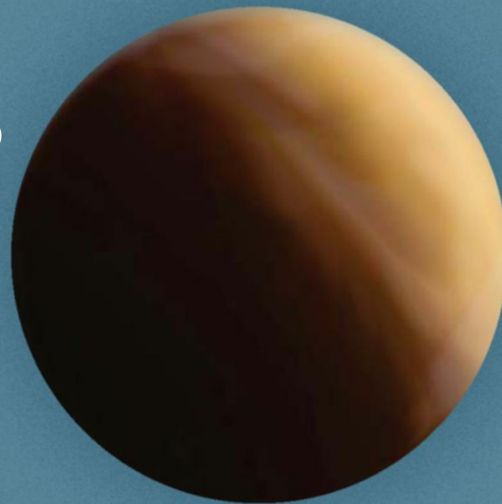


TITAN

Titan is intriguing because it fits a few of Sagan's criteria. Most notably, while its atmosphere is 98.4 per cent nitrogen, it also contains 1.4 per cent of methane. The exact origin of this methane remains a mystery. It could be related to bacteria, or it could be caused by natural gas. Titan is also thought to have an underground ocean, so the idea it could support life is not too far-fetched. It's also the only place other than Earth with bodies of liquid on its surface, albeit in the form of liquid hydrocarbons.

Criteria met?

CH_4



GJ 1132B

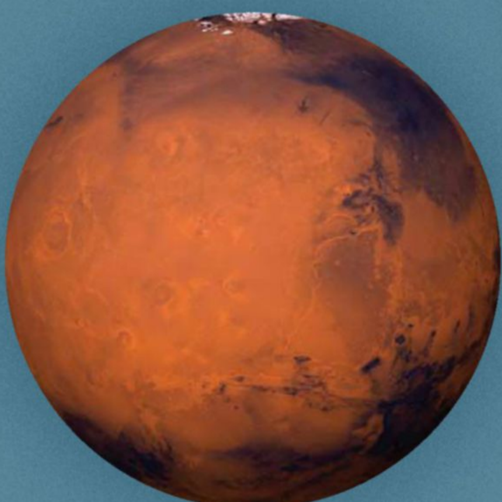
This exoplanet – announced in April 2017 – is extremely enticing because it is an Earth-sized world orbiting in the habitable zone of its star. Measuring 1.4 times the size of our planet, some have suggested this may be one of our best bets for life to date. As the planet passed in front of its red dwarf star 39 lightyears away, scientists saw that the planet looked a bit bigger in one wavelength of light, suggesting it has an atmosphere. If this is true, it could well have liquid water on its surface – key for life.

Criteria met?

FRB 121102

Fast radio bursts (FRBs) continue to confuse astronomers, as no one is quite sure what's causing them. They are bursts of radio waves lasting up to just five milliseconds, and we can see them in other galaxies in the universe. Various phenomena have been ruled out as being their cause, leading some to very tentatively suggest that they could be signals from a technological alien race. That's a bit far-fetched at the moment, but the truth is we still don't know what causes FRBs. Until we can find that out, the alien theory cannot be definitively cast aside.

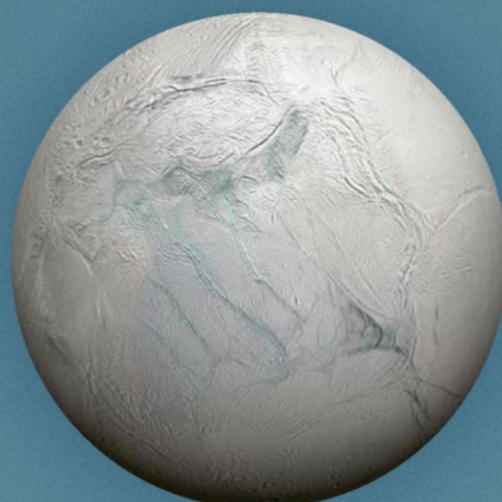
Criteria met?



MARS

Of all the places in our Solar System, Mars has long looked like one of the best bets for life. In recent years we have found evidence for liquid water trickling on its surface, suggesting there are vast reservoirs underground. It also has an unknown source of methane, which is currently being investigated by the European ExoMars mission. In its past, we also think Mars had a thicker atmosphere and perhaps supported oceans and seas on its surface. It may appear pretty dead, but the search is well under way for ancient life on Mars.

Criteria met?



ENCELADUS

This icy moon is thought to house a vast ocean of water under its surface, perhaps containing more water than there is on Earth. How do we know this? Well, some of this water continues to spout from this moon's southern hemisphere. The Cassini mission sampled this water directly and within it found some of the key ingredients for life. This included hydrogen, which on Earth provides fuel for organisms on the seafloor. Like our Moon, however, finding an ingredient for life does not mean it's present. Future missions will confirm if it's really there.

Criteria met?

"Titan is the only place other than Earth with bodies of liquid on its surface"

The James Webb Space Telescope

How NASA's next telescope could improve our search for life

In October 2018, NASA will launch one of its most anticipated missions ever. This is the James Webb Space Telescope (JWST), a vast observatory twice the size of the Hubble Space Telescope that will be positioned beyond the orbit of the Moon. The goal of this telescope is to probe the universe, looking at distant galaxies and fascinating supernovae. But it will also be training its 18 hexagonal mirrors on exoplanets, in the hope of studying their atmospheres and potentially finding biosignatures.

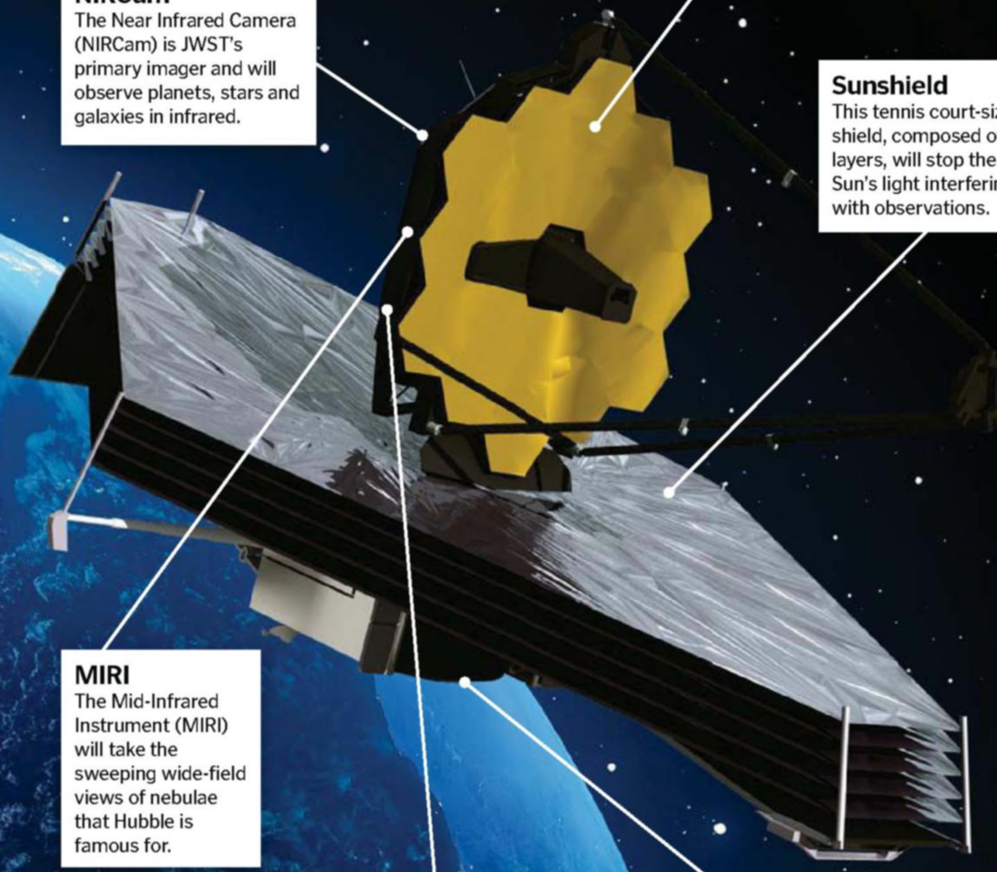
Several intriguing planets for study have been identified so far. Perhaps the most enticing are Earth-sized worlds around red dwarf stars. As these stars are dimmer than stars like our Sun, we can more easily image planets in orbit and study their atmospheres.

Observing worlds in infrared, JWST will study the light of stars coming through the atmospheres of exoplanets to try and work out their atmospheric composition. It will also attempt to directly image planets by blocking out the light of the star. This will appear as nothing but a small speck of light, rather than a broad global view of a world. But by studying this speck it may be possible to watch the seasons change and even work out if vegetation is present on a planet's surface.

The JWST will provide a cavalcade of new information about other worlds, and following the Sagan criteria it may get us closer to finding out if there are any other truly habitable worlds in the universe.

How the JWST works

The various pieces of equipment that will allow us to study other worlds



NIRCam
The Near Infrared Camera (NIRCam) is JWST's primary imager and will observe planets, stars and galaxies in infrared.

Primary mirror
Equipped with 18 hexagonal mirrors made of beryllium and coated with gold, this will gather light from distant targets.

Sunshield
This tennis court-sized shield, composed of five layers, will stop the Sun's light interfering with observations.

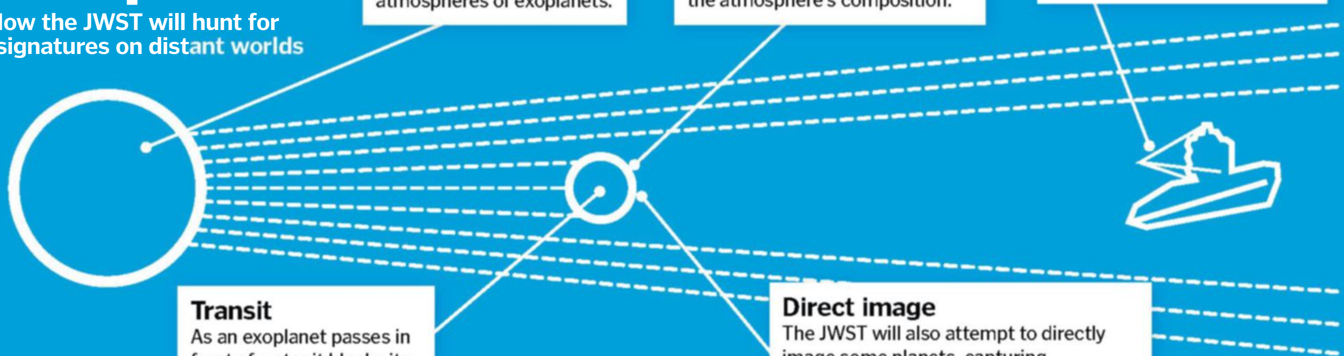
MIRI
The Mid-Infrared Instrument (MIRI) will take the sweeping wide-field views of nebulae that Hubble is famous for.

NIRSpec
The Near Infrared Spectrograph (NIRSpec) will be used to study the physical properties of celestial objects.

Star trackers
These tiny telescopes will monitor star patterns to tell the observatory which way to look to find a target.

Studying atmospheres

How the JWST will hunt for biosignatures on distant worlds



Star
The JWST will observe the light of other stars as it passes through the atmospheres of exoplanets.

Atmosphere
As light passes through the atmosphere, the JWST can measure its intensity to work out the atmosphere's composition.

Distance
The worlds JWST will study will be up to tens of lightyears away from our planet.

Transit
As an exoplanet passes in front of a star it blocks its light, known as a transit.

Direct image
The JWST will also attempt to directly image some planets, capturing low-resolution views of their appearance.

Integrated Truss Structure

How the International Space Station is held together in orbit

The International Space Station (ISS) might look like a rather hodgepodge collection of modules and solar panels, but it's actually laid out in a pretty ordered manner, with a backbone known as a 'truss' keeping the whole station shipshape.

This truss is better known as the Integrated Truss Structure (ITS). In total it measures 109 metres in length, providing a sturdy backbone for the orbiting station. Since construction began in 1998, the truss has continuously been added to, mostly with Space Shuttle missions, allowing new components to be attached to the station.

The truss forms the long part of the station along which everything is attached. Any truss segments to the 'port' side of the station are labelled P. 'Starboard' segments are S, and Zenith (up and down) are Z.

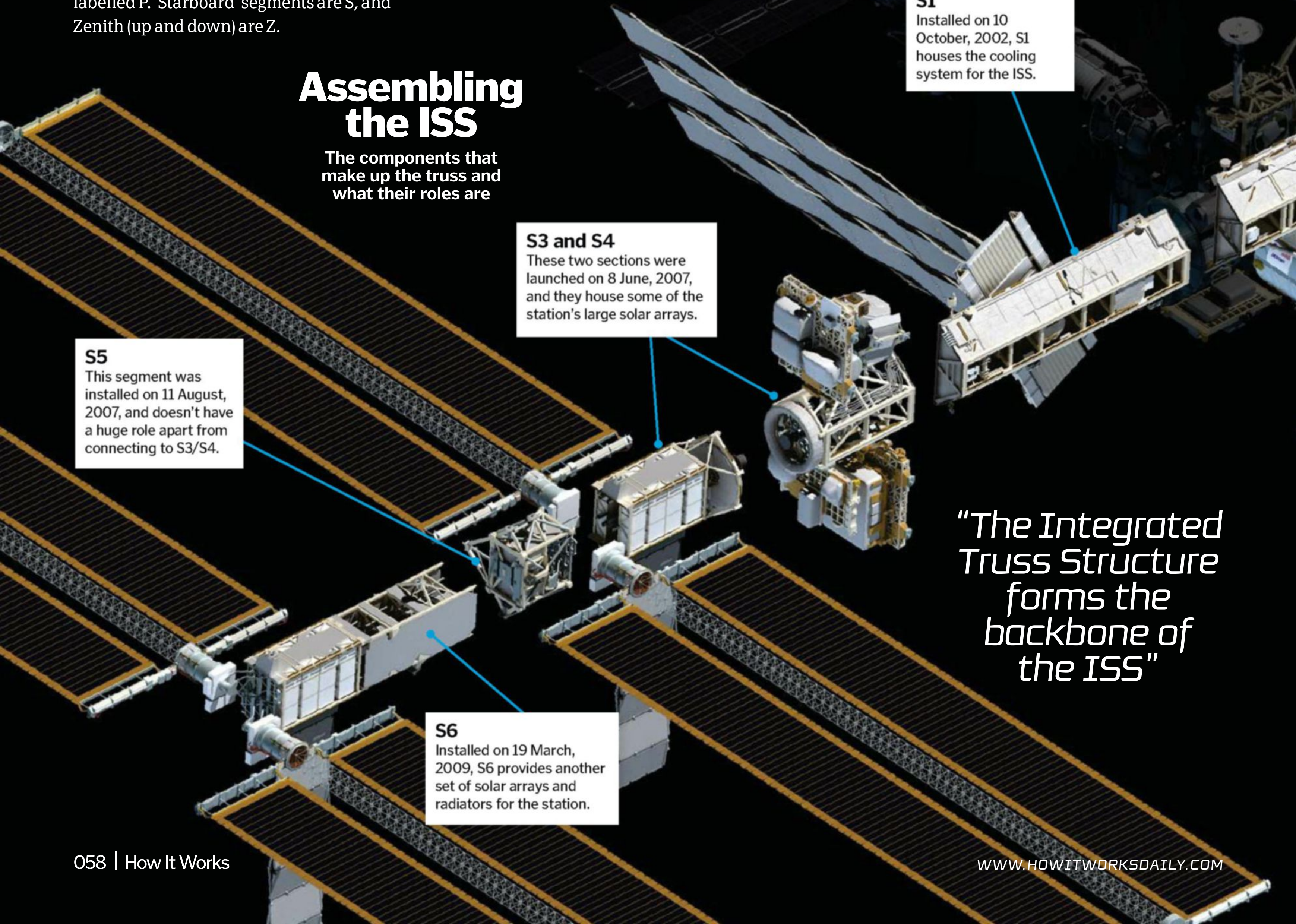
There have been 11 different truss segments attached to the ISS over the years. Apart from being places to attach things, they also contain all the electrical and cooling utility lines. And when astronauts go on spacewalks, they use railings attached to the truss to move around.

Construction of the truss is essentially complete, so until it's retired in the 2020s, the ISS won't change its appearance much.

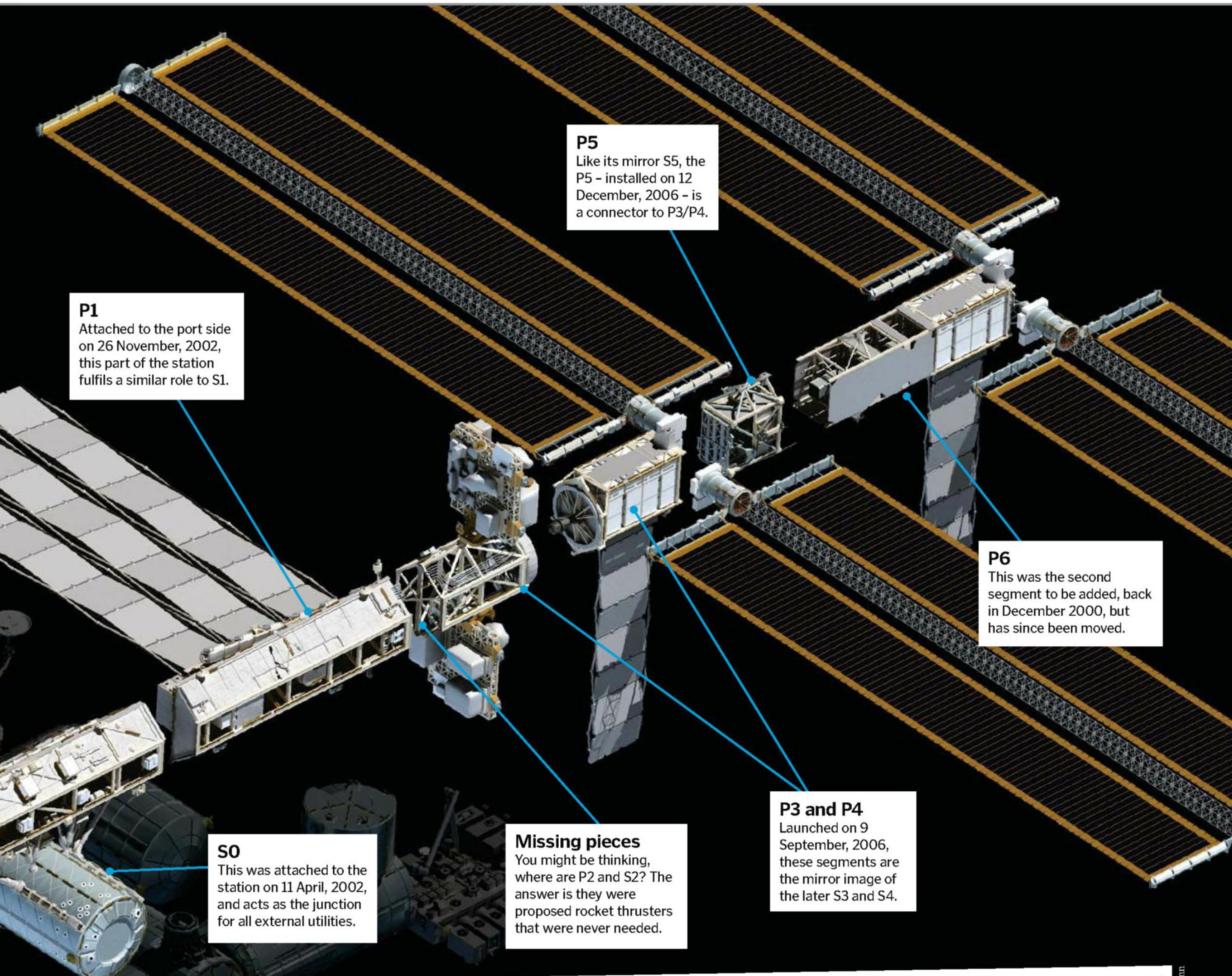
Above: the essentially complete ISS truss structure in 2011

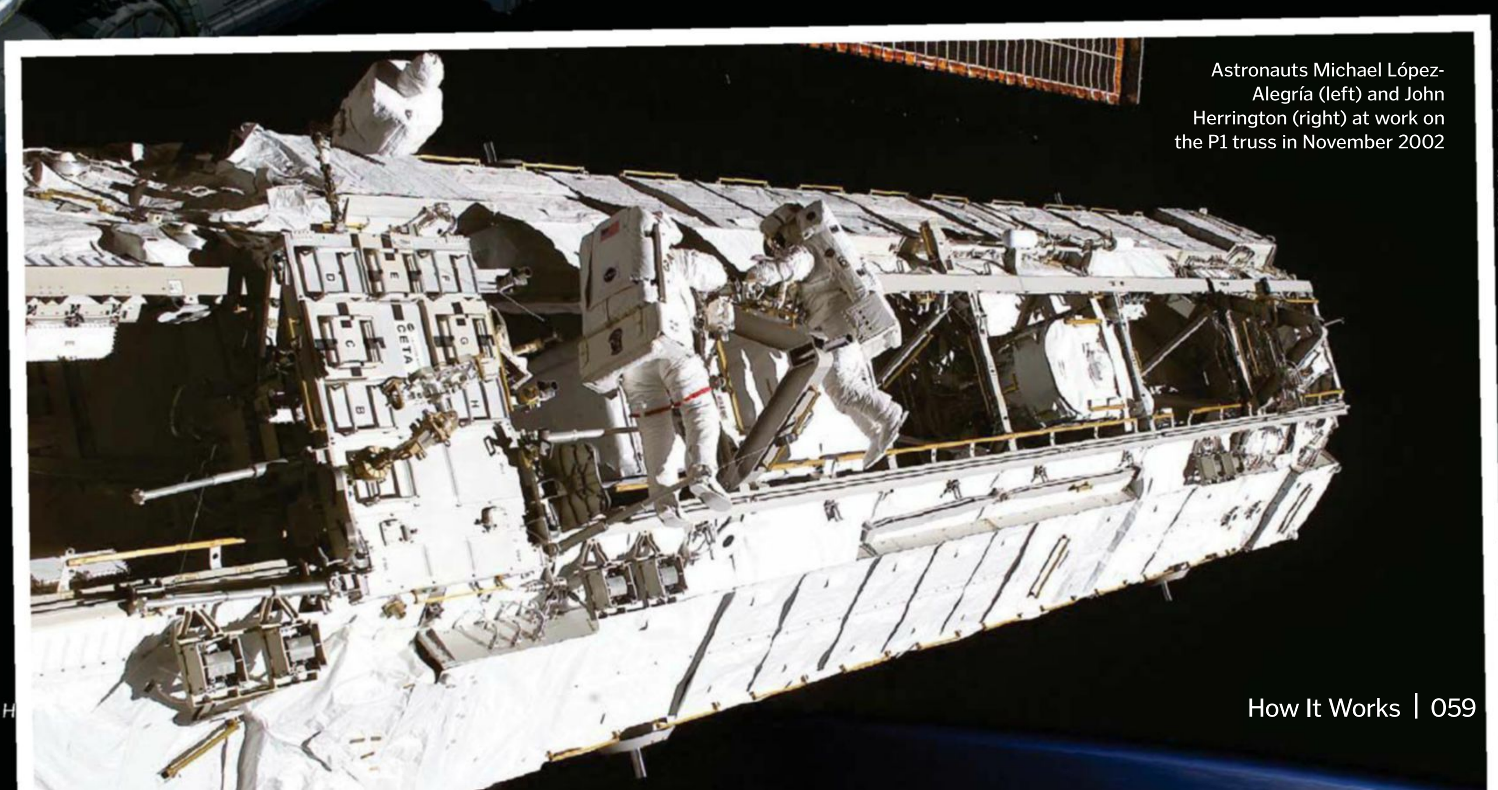
Assembling the ISS

The components that make up the truss and what their roles are

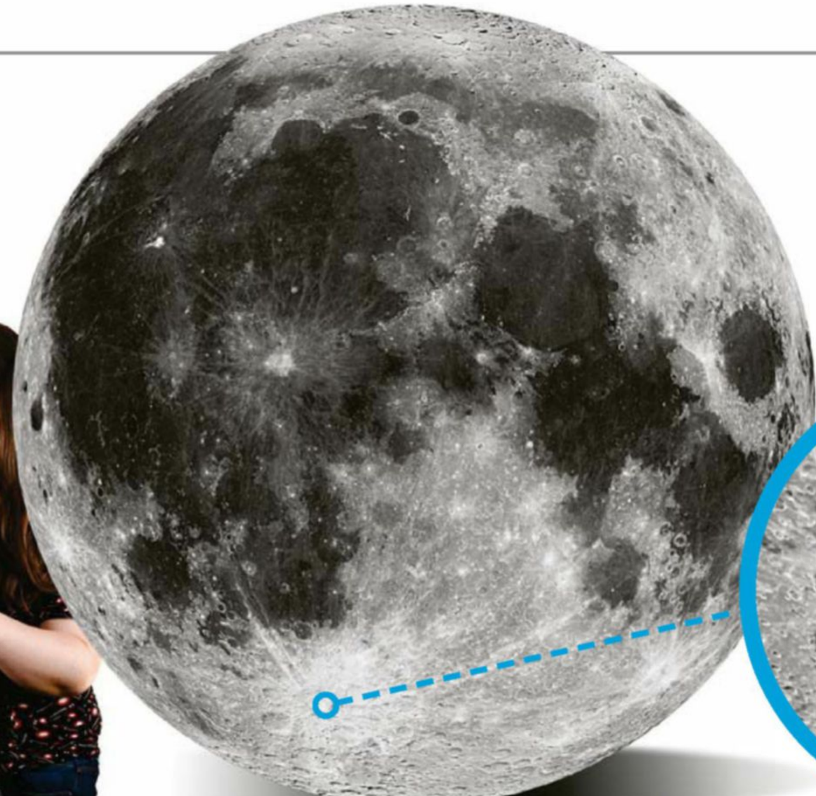


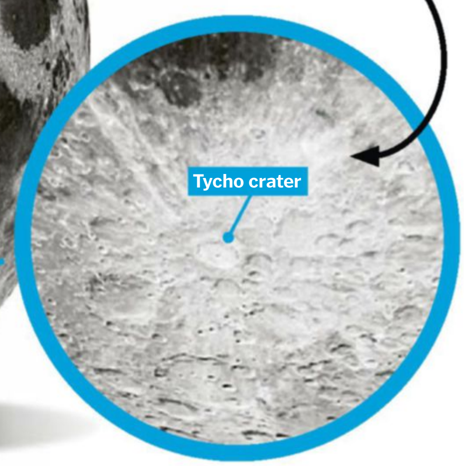
"The Integrated Truss Structure forms the backbone of the ISS"





Astronauts Michael López-Alegría (left) and John Herrington (right) at work on the P1 truss in November 2002





TIP 1
Use a lunar map
The first thing to do is to get yourself a map of the surface of the Moon. You can find one of these easily enough online, and with this you'll be able to identify some of the key features on the surface.

TIP 2
Explore!
The Moon is host to vast maria (hardened lava), craters, mountains, ridges and much more. Make sure you brush up on some regions of interest, like the prominent Tycho crater that's easily visible near the south pole.

HOW TO OBSERVE THE MOON

What can you see on the lunar surface with the naked eye or a telescope?

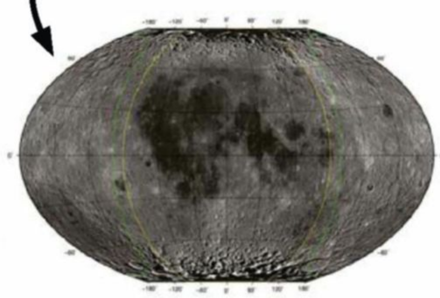
Throughout human history, the Moon has been a fascinating target of observation. From its more mythical beginnings, we now know the Moon to be our largest natural satellite, and it was possibly formed from the same rock under your feet right now by a collision 4.5 billion years ago.

With the naked eye you can easily start observing some of the Moon's larger features. From the dark patches that once brimmed with lava to its numerous craters, there are plenty of sights to behold.

However, by using binoculars or a telescope you can see some of its more intricate features, such as the terminator, where sunlight casts shadows on the surface, or even the regions in which the Apollo spacecraft landed. Here we'll give you some top tips for getting the most out of your lunar observations.

TIP 3
Look along the terminator
Perhaps one of the best times to observe the Moon is not when it's full, but when it's a crescent. Here, by looking at the border between light and dark, you'll be able to make out some more detail on the surface.

TIP 4
Look for subtle differences
While the same face of the Moon always points towards us, it actually wobbles a bit in its orbit (called libration). This means that at its edges you can sometimes see different regions that were not visible before.



TIP 5
Observe throughout the month
The Moon goes through a cycle every 29.5 days from full Moon to new Moon (when little to no sunlight is reflected on the surface). Viewing it at different times can give you a whole new perspective.

TIP 6
Use the right equipment
If you're going to use a telescope, make sure you get a Moon filter. This will cut out the bright glare of the reflected sunlight, so you'll more easily be able to train your eye on the surface by adjusting the brightness.

Astrolabes

The ancient computers that give you the time of day by mapping the stars

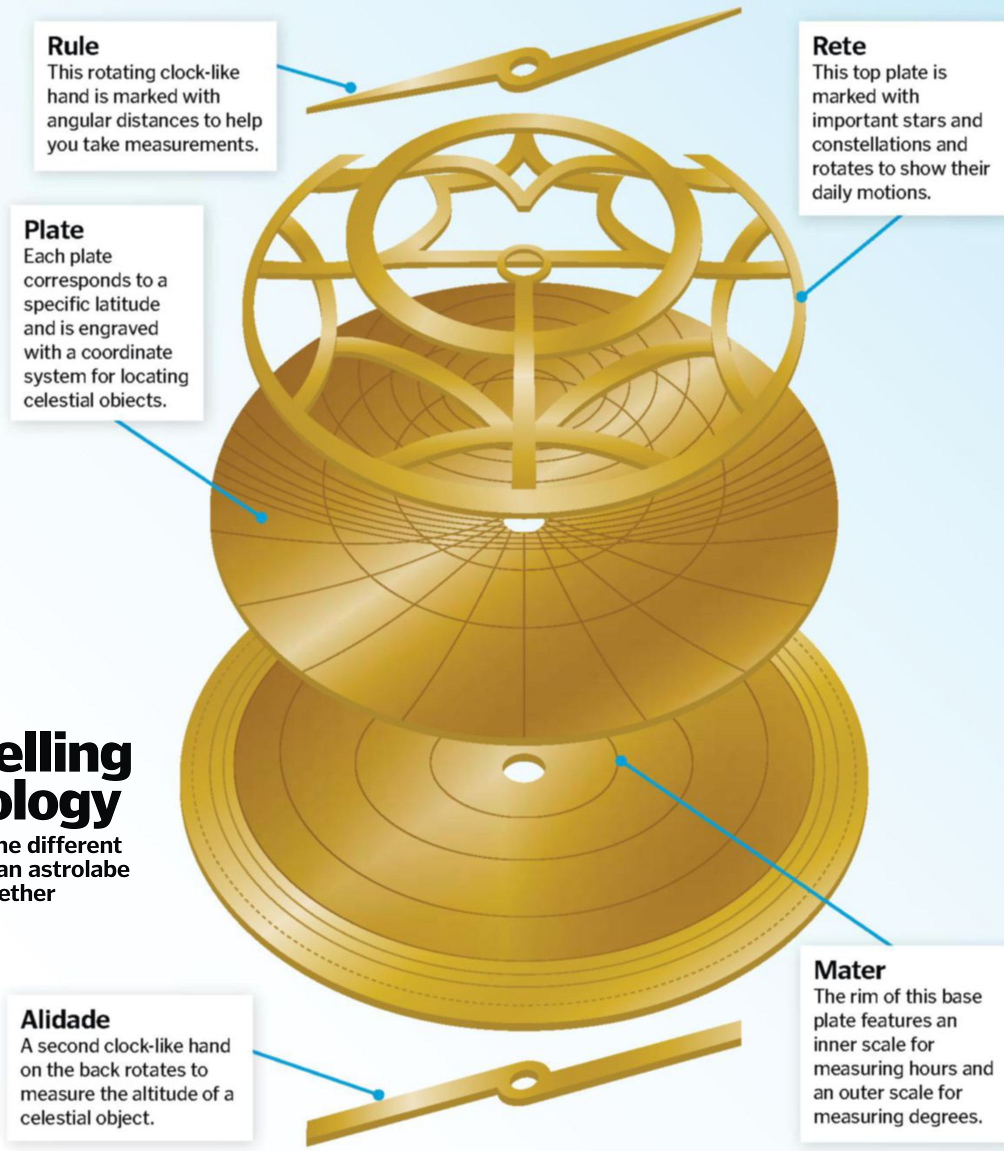
Before clocks, humans used the Sun and night's sky to measure time, and they invented astrolabes to help them do it. The concept for these ancient astronomical devices first appeared before 150 BCE, but they were not built until a few centuries later. Their primary function was to calculate the altitude of celestial bodies such as the Sun and other stars, which could be used to tell the time during the day or night. However, they can also be used for plotting and predicting astronomical phenomena such as sunrises and sunsets, calculating the time of year and determining latitude, and so they proved useful to sailors as well as astronomers.

Astrolabes were typically 15cm in diameter and made from wood or brass

"The concept first appeared in 150 BCE"

Time-telling technology

Discover how the different components of an astrolabe work together



Black widow pulsars

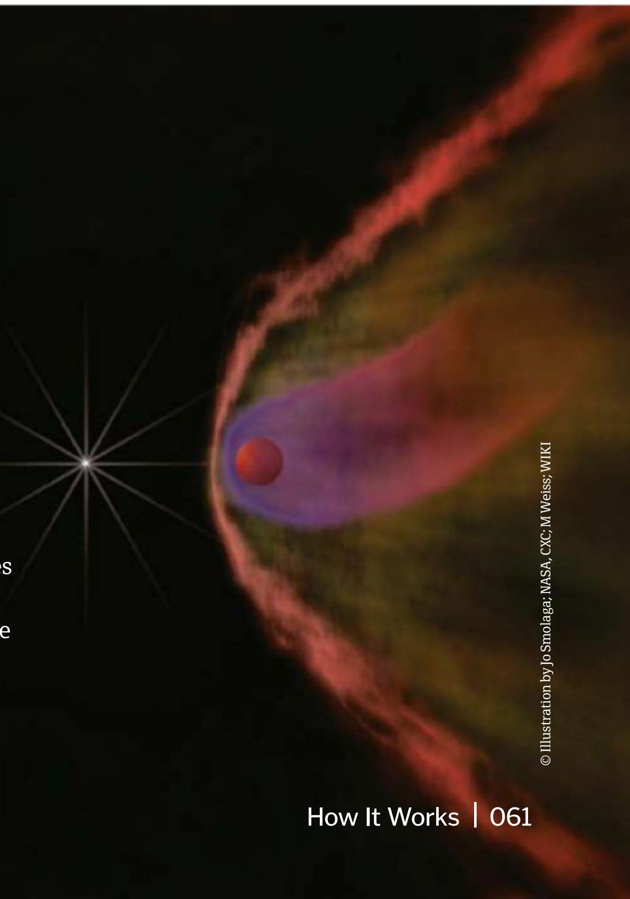
The spinning stars that will destroy their cosmic companions

When a star dies in a supernova the core of the deceased star is crushed under extreme pressure, causing it to become either a black hole or a neutron star. A pulsar is a neutron star that is spinning at a few thousand revolutions per minute (rpm). Some of these pulsars spin up to 43,000rpm and form a strong magnetic field.

The combination of magnetic forces and the spinning speed drives beams of electromagnetic radiation from the pulsar, including gamma rays. When these millisecond pulsars are near another normal or low-mass star they create binary star systems that can be categorised into two groups: redbacks and black widows.

Both of these are rare star systems and are named after spiders infamous for devouring their companions. This is because, as its namesake suggests, the pulsar will eventually completely destroy its less dense neighbour, slowly but surely consuming it entirely.

The spider pulsar completely destroys its binary partner as high-energy particles annihilate it. When the gamma-ray beam passes over the smaller star it can heat it to more than 11,650 degrees Celsius (twice as hot as the surface of the Sun). This, alongside solar winds and the hostile conditions of space, strips material from the companion star, slowly evaporating it over millions or billions of years.



Juno's discoveries

What this NASA spacecraft has taught us about Jupiter one year into its mission

Ammonia storms

In Jupiter's atmosphere, it seems that ammonia is sucked up from deeper within the planet. This feeds giant weather systems, such as the white spots in its upper atmosphere.

Weird poles

Jupiter is encircled by iconic bands of storms, but at its north and south poles, Juno has discovered the pattern of storms is much more random and erratic.

Unusual dynamo

The cause of Jupiter's magnetic field may not be its core, like Earth. Instead, Juno has found the dynamo powering it may be near Jupiter's surface.

Fuzzy core

Juno is trying to work out if the core of Jupiter is solid. Based on gravity measurements so far, it appears to be irregular, mixing with liquid upper layers.

Strong magnetic field

Juno has found that Jupiter's magnetic field reaches up to 7.766 Gauss in some areas, which is twice what was expected, and ten-times stronger than Earth's.

An image of Jupiter's unusual south pole taken by Juno

AIRPORT SECURITY

The equipment that helps keep passengers safe while they travel

For many of us, the slow, shuffling queue at airport security is a necessary inconvenience; a right of passage we all must endure before we can begin to enjoy a trip abroad. But few take the time to consider the impressive technology and equipment that has been developed to keep us safe while we're in the air. In this feature we'll explain the science behind this comprehensive screening process. But first we should ask ourselves why we need airport security.

When posed this question, most will immediately think of the terror attacks against the US on 11 September, 2001. This atrocity shook the world and was the catalyst that drove levels of security to the heights found today. But we have to go back further, to the 1960s and 1970s, to discover the origins of the all too familiar X-ray scanners and metal detectors.

An American airport prior to 1973 would be an alien place to the modern traveller. Identification wasn't necessary for internal flights, passengers were rarely scanned, and only suspicious individuals who set off a detector were frisked. It may come as no surprise then that this relatively lacklustre approach to security led to heightened criminal activity in the air; in 1969 there were 40 hijacking attempts made in the US alone. But the need for additional security measures was driven home hardest by one of the most intriguing heists in modern history: the DB Cooper hijacking.

In 1971, a polite and quiet man who called himself Dan Cooper paid in cash for a one-way ticket from Portland to Seattle. Once aboard the aircraft, he showed an air stewardess the contents of his briefcase, which was packed full of wires and red-coloured sticks – a bomb. Cooper demanded $200,000 and four parachutes, and once his demands had been met he released the other passengers, kept the crew aboard and commanded the plane to take off. At a low altitude of roughly 3,000 metres, the rear door exit was opened and, with a parachute on his back and the money bound to his chest with

Online check-in was first introduced by Alaskan Airlines in 1999

Bomb detection

How does airport security uncover explosives and keep flyers safe?

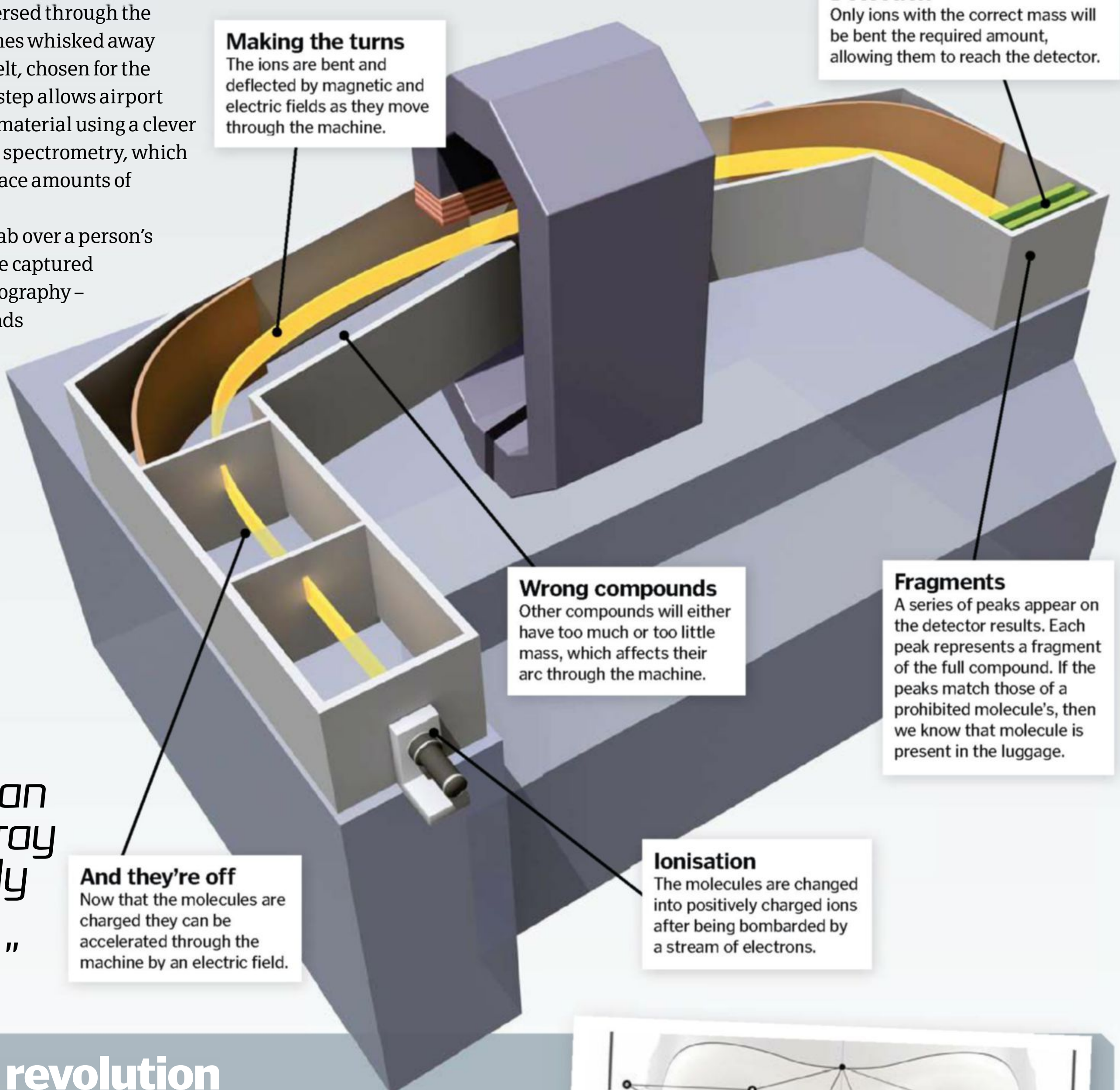
Detecting explosive material is of paramount importance to air security, and substances are searched for at multiple stages. For example, after our luggage has traversed through the X-ray scanner, it's sometimes whisked away down another conveyor belt, chosen for the so-called 'swab test'. This step allows airport security to spot explosive material using a clever technique known as mass spectrometry, which is capable of identifying trace amounts of prohibited compounds.

By simply running a swab over a person's luggage and separating the captured molecules by gas chromatography – which separates compounds based on how long it takes them to travel through a gas column – the mass spectrometer can then reveal an array of potentially dangerous compounds, ensuring even heavily disguised forbidden items are discovered.

> "Separating captured molecules can reveal an array of potentially dangerous compounds"

Mass spectrometry

Meet the world's most accurate set of scales

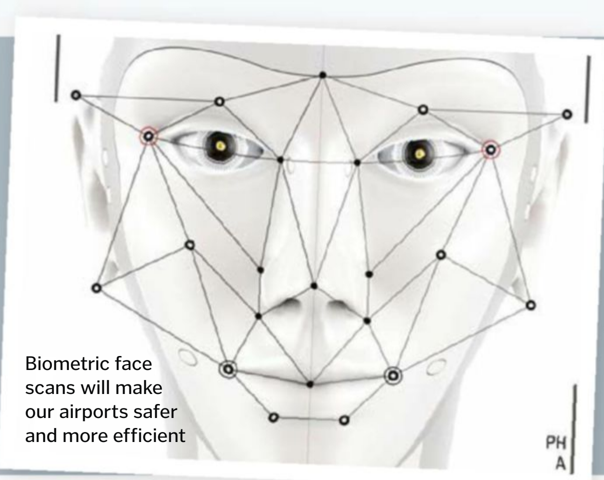


Biometric revolution

Biometrics – where data about you is gathered through your biology – is becoming increasingly popular for both security and convenience. We can now lock our data behind fingerprint scanners, iris scanners, and even whole face scanners, and this technology will likely become ever more present in airports in the coming years.

Already being trialled is the 'biometric pathway', which takes a face scan of each passenger as they arrive at the airport terminal and begin the digital check-in process. The software first pinpoints a collection of landmark locations on each traveller's face, and from there it paints a unique identification using features individual to each person, such as the distance between the eyes, width of the nose and length of the jaw line.

By comparing the biometric analysis of every passenger to a security database, known or wanted criminals can be swiftly identified. In addition, the advocates of face scanning technology believe it could be used for all of the terminal checkpoints, making passing through check-in, security and boarding all much simpler.



Biometric face scans will make our airports safer and more efficient

cords, Cooper jumped out into the night. He was never found.

This notorious and audacious heist proved rather inspirational for other criminals, and a number of copycat attempts followed. By January 1973, the government had decided to implement screening technologies able to expose weapons and explosives at security checkpoints, and the number of hijackings inevitably fell drastically soon after. Modern security had been born, and it has continuously evolved in the following years to cope with ever-changing threats.

The metal detector, for example, which has been in use for decades, is growing redundant for modern dangers. Criminals have shifted from metal guns and knives to non-metallic explosives, and security technology has had to adapt accordingly. This has led to the rise of the advanced radio wave-emitting millimetre-wave scanner and X-ray scattering techniques, which are able to probe passengers for hidden objects

> "Handheld 'sniffers' may soon be a common sight, replacing dogs"

without the invasive act of frisking. These technologies are not without their own drawbacks, however, and we will explore user's privacy issues and address the safety concerns of the new equipment further on in this feature.

Innovative measures go further than just body scanners – airports are now often equipped with bomb detection equipment, which is derived from Nobel Prize -winning science. And handheld chemical 'sniffers' may also soon be a common sight, replacing dogs.

There's also a higher emphasis on convenience than before, with automated passport scanners and extra safety behind the scenes, such as biometric fingerprinting technology to permit entry to airport staff.

Flying is one of the most convenient means of travelling. Through ingenious design, aircraft are also statistically the safest vehicles to make a journey in, and airport security has played a pivotal role in ensuring that it remains this way. Separating your liquids and your laptops from the rest of your luggage, removing your shoes, and being scanned may feel at times like an inconvenience, but with these measures the equipment is most effective and most able to keep us safe. Now that we have the ability to spot objects under layers of clothing, make comprehensive scans of traveller's luggage, and detect mere traces of dangerous compounds, our airports have never been safer.

Body scanners

There are several techniques, but which is the best option for passenger screening?

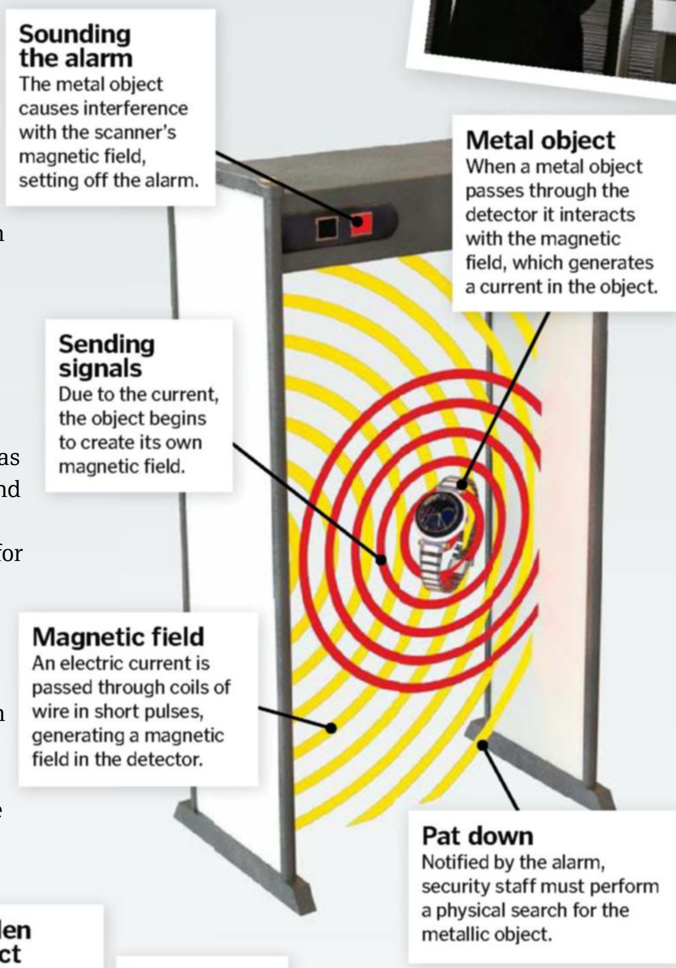
METAL DETECTOR

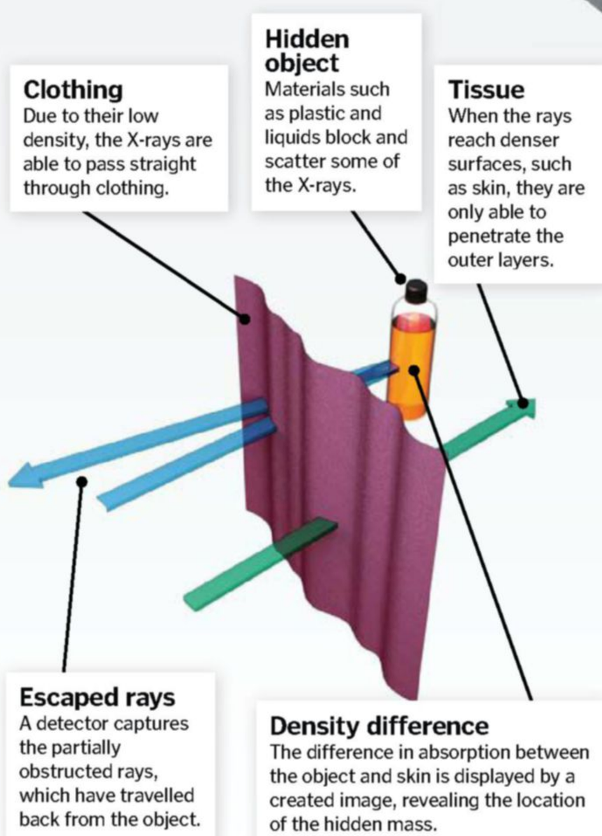
Purpose

Metal detectors have played an integral role in the passenger screening process for over 40 years. Their ability to detect metallic materials, which are key components of many forbidden items including knives, guns and explosives, has made the full body scanners and their handheld counterparts essential pieces of equipment for airport security.

Is it safe?

Although metal detectors do emit electromagnetic radiation via coils, which the passenger walks through as they pass through the detector, these are in the form of harmless low-frequency radio waves.





BACKSCATTER X-RAY

Purpose

With the rise of the plastic explosive and the recent failed attempts in the form of shoe bombers and pants bombers, new technologies have been developed that can identify non-metallic objects under layers of clothing. Using lightly probing X-rays, backscatter scanners can identify hidden objects by how they obstruct the emitted radiation.

Is it safe?

The X-rays used by this technology are low-energy compared to those used in hospital scans, making them much safer. The radiation dose received is lower than the amount accrued during two minutes of flying in an aircraft.

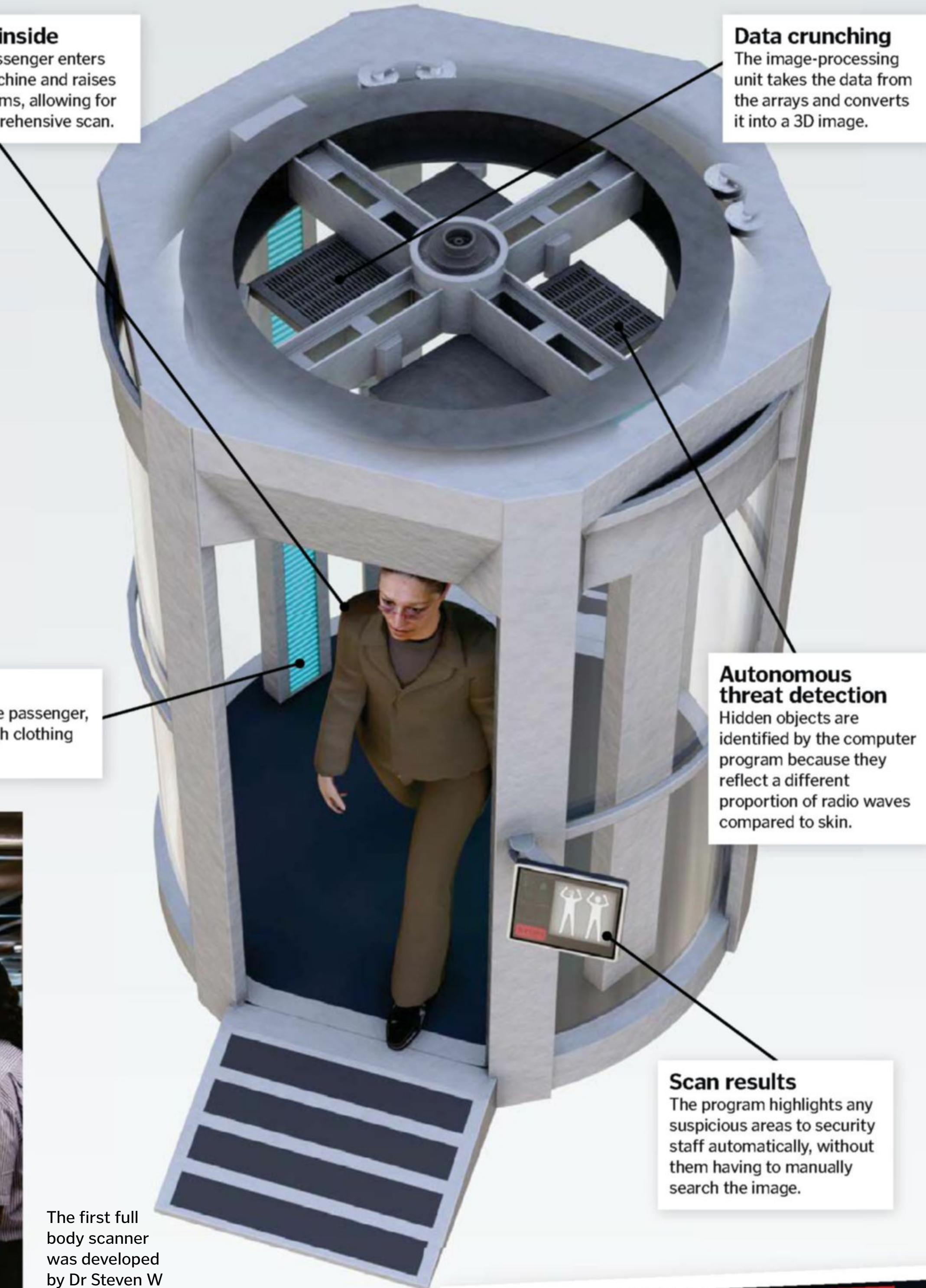
MILLIMETRE-WAVE

Purpose

The goal of the millimetre-wave is to produce a three-dimensional scan of each passenger that can reveal any objects hidden under clothing. Modern millimetre-wave scanners autonomously alert security to areas on the body where a prohibited object may be hidden, saving the staff from having to manually search the scan.

Is it safe?

Millimetre arrays emit non-ionising radio waves, which are believed to be unable to cause DNA mutation or tissue damage. The waves can penetrate through clothes but not denser surfaces such as skin.



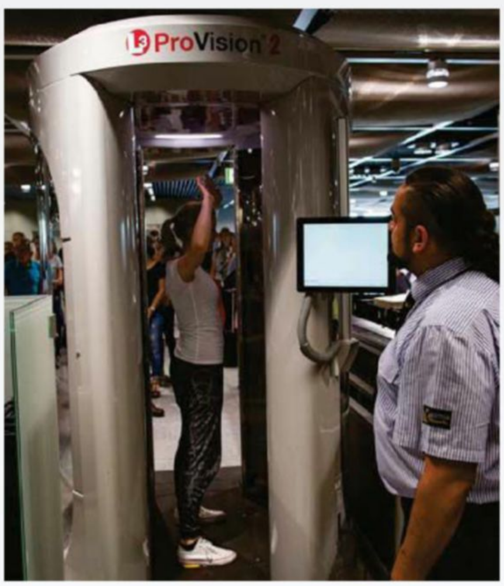
Step inside
The passenger enters the machine and raises their arms, allowing for a comprehensive scan.

Data crunching
The image-processing unit takes the data from the arrays and converts it into a 3D image.

Antenna arrays
Dual antenna-masts sweep around the passenger, emitting radio waves that pass through clothing but bounce off denser materials.

Autonomous threat detection
Hidden objects are identified by the computer program because they reflect a different proportion of radio waves compared to skin.

Scan results
The program highlights any suspicious areas to security staff automatically, without them having to manually search the image.



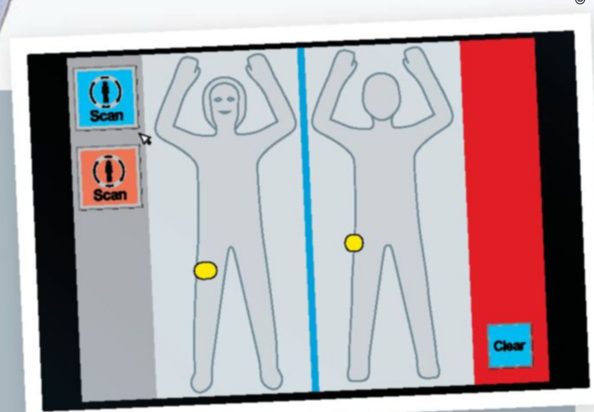
The first full body scanner was developed by Dr Steven W Smith in 1992

Privacy concerns

In December 2009, a failed terrorist attack involving explosives embedded into underwear inspired the US government to take action. The attempted bomber's ability to board the aircraft with dangerous materials highlighted the metal detector's growing inability to handle bomb threats, and new machines were needed.

Fast-forward just a few years and backscatter X-ray scanners and millimetre-wave machines are becoming ever more commonplace in airports across the globe. Unlike detectors, these machines are able to accurately display disguised objects of many materials. They achieve this with an ability akin to Superman – by seeing through our clothes.

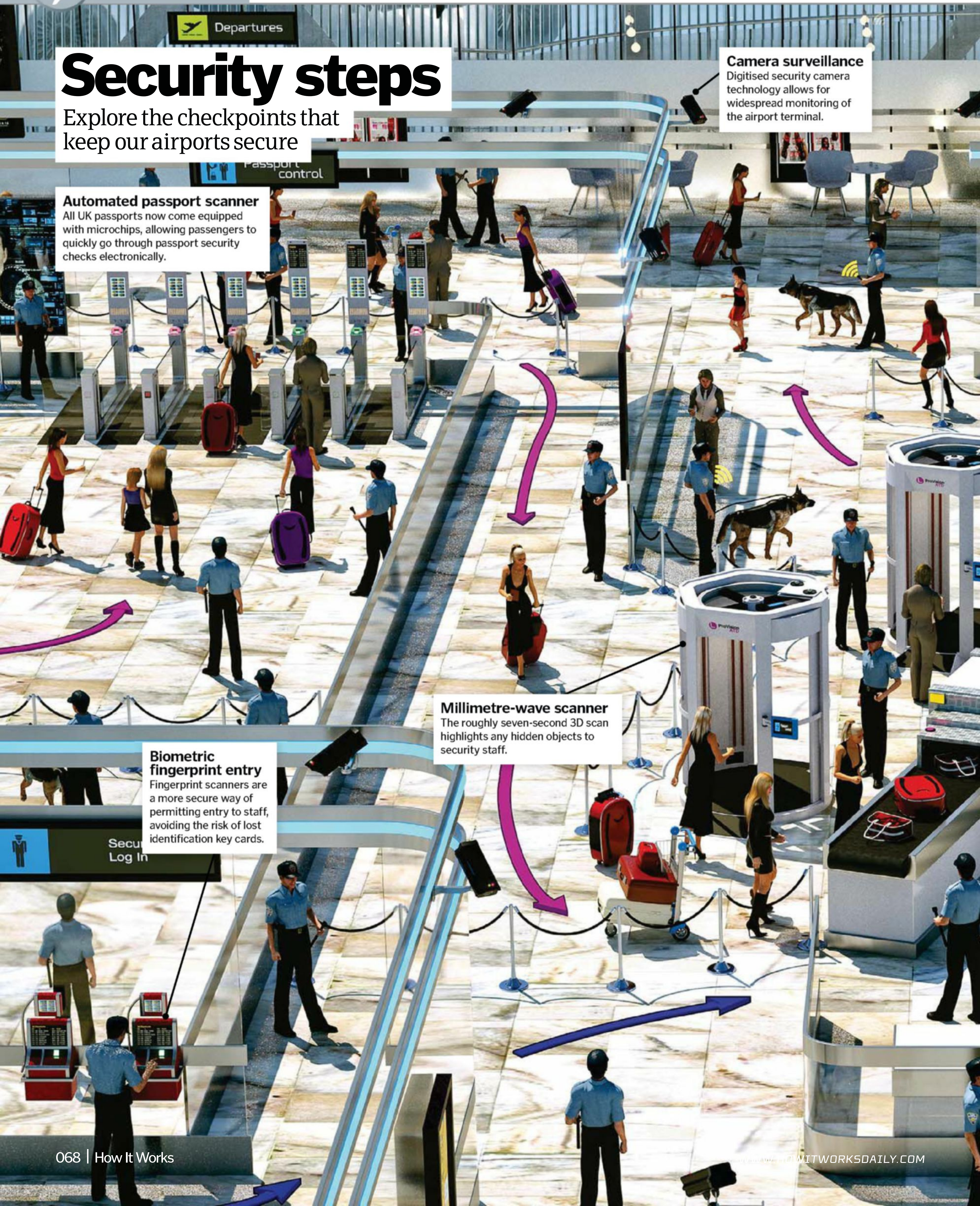
Although passengers appreciated the need for improved security measures, many were unhappy with the images produced, which essentially stripped the passenger of their clothing for all security staff to see. Fortunately, clever computer software has now helped to rectify the issue by processing the scan results autonomously. The results are displayed on a generic 'gingerbread man' image, and any suspicious areas are highlighted by yellow boxes, allowing for a focused physical search.



The generic 'gingerbread man' image has allowed passengers to retain their privacy

Security steps

Explore the checkpoints that keep our airports secure



Automated passport scanner
All UK passports now come equipped with microchips, allowing passengers to quickly go through passport security checks electronically.

Camera surveillance
Digitised security camera technology allows for widespread monitoring of the airport terminal.

Millimetre-wave scanner
The roughly seven-second 3D scan highlights any hidden objects to security staff.

Biometric fingerprint entry
Fingerprint scanners are a more secure way of permitting entry to staff, avoiding the risk of lost identification key cards.

Why are electronic devices scanned separately?

We've all been there – stripped of our belts and shoes, our pockets emptied, our liquids separated, thinking that we're finally ready to pass through security. And then we remember that we've left our laptop in our hand luggage and we scramble to dig it out before it reaches the X-ray scanner. It's an annoying part of the process – but why do we need our electronics to be scanned separately anyway?

The answer lies in their density. Due to their many component parts, laptops, DVD players and gaming consoles can obscure other objects in your bag, disguising items placed underneath from the X-rays emitted from the top of the scanner. As well as this, for security staff to get a good look at the dense object (they only have about three seconds) it is best scanned by itself, because there have been incidences of people concealing items inside them.

Security only has a few seconds to assess our luggage, so dense objects are scanned individually

Automated tunnel washes

How do these giant machines clean our cars?


Sensors in the car wash mechanisms detect the position and shape of your car and move around it accordingly

The automated tunnel car wash is the largest robot most of us will interact with in daily life. With a tough aluminium, rust-resistant frame to carry the machinery and a conveyer belt able to move more than 30 tons of vehicle, a combination of chemicals, high pressure and mechanical friction ensures a thorough clean.

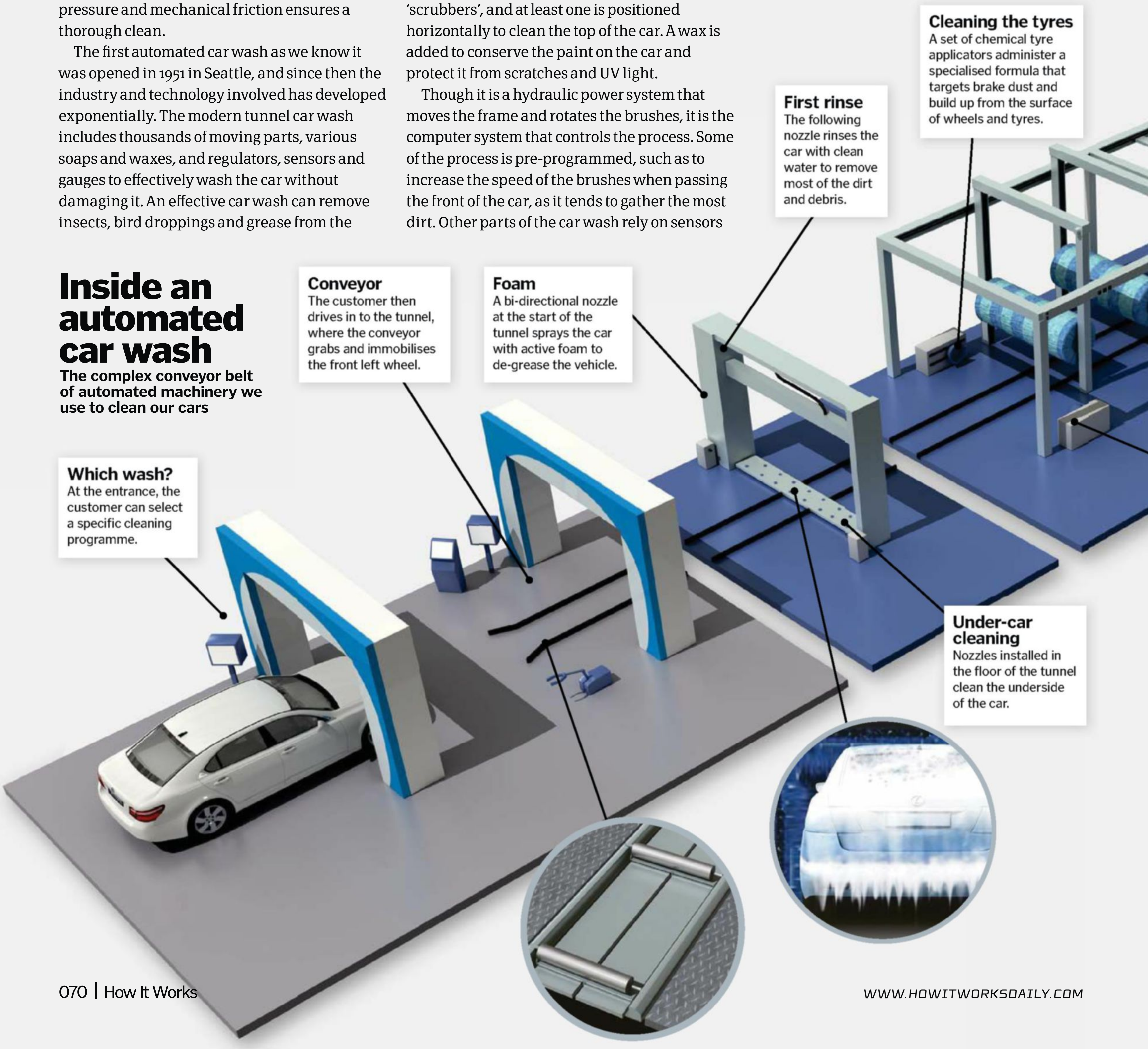
The first automated car wash as we know it was opened in 1951 in Seattle, and since then the industry and technology involved has developed exponentially. The modern tunnel car wash includes thousands of moving parts, various soaps and waxes, and regulators, sensors and gauges to effectively wash the car without damaging it. An effective car wash can remove insects, bird droppings and grease from the surfaces of the vehicle in just a few minutes.

The process generally starts with pre-soakers, usually with a mild alkali first and then rinsing with a mild acid. This is followed by the addition of detergents to deep clean. The main section contains two to five brushes known as 'scrubbers', and at least one is positioned horizontally to clean the top of the car. A wax is added to conserve the paint on the car and protect it from scratches and UV light.

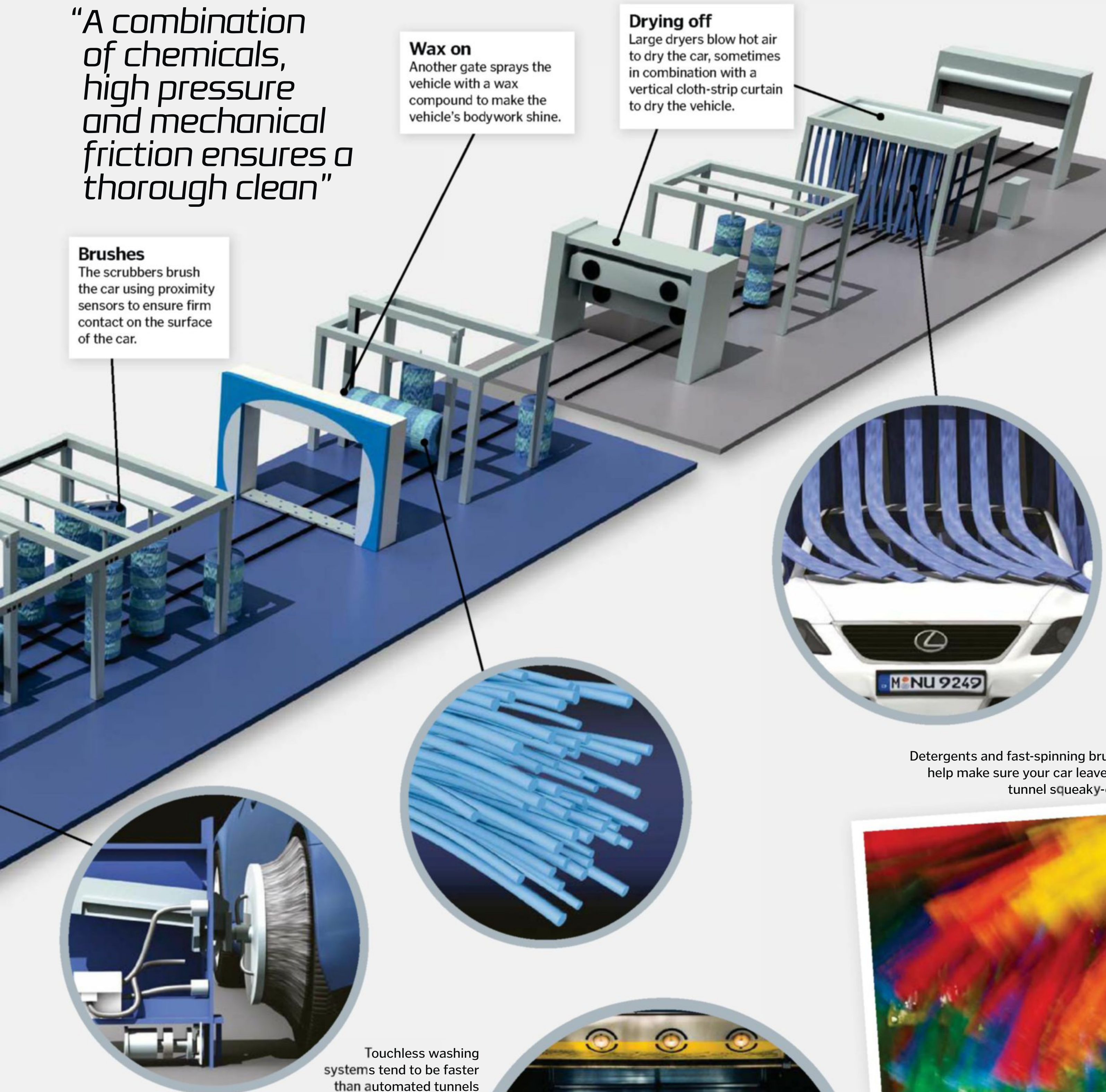
Though it is a hydraulic power system that moves the frame and rotates the brushes, it is the computer system that controls the process. Some of the process is pre-programmed, such as to increase the speed of the brushes when passing the front of the car, as it tends to gather the most dirt. Other parts of the car wash rely on sensors and the feedback from them, such as photoelectric systems that are responsible for positioning and contouring detection. In the final drying stage of the car wash, the computer repeats the movement of the brushes memorised from earlier stages.

Inside an automated car wash

The complex conveyor belt of automated machinery we use to clean our cars



"A combination of chemicals, high pressure and mechanical friction ensures a thorough clean"



Detergents and fast-spinning brushes help make sure your car leaves the tunnel squeaky-clean

Touchless washing systems tend to be faster than automated tunnels

Touchless car wash

One of the more recent advancements in the car wash industry has been the introduction of fully automated, touchless washing systems. The touchless system uses nozzles and moves around the stationary car and involves no contact from brushes or fabric. It first wets the car by spraying water from low-pressure nozzles, before applying a specialised car wash soap. The nozzles then blast the car with high-pressure water to clean the soap off the car. It is then possible to add wax or clean the tyres using the same technique.

Points of sail

How do sailors use the wind to their advantage?

A true sailor has the ability to harness the power of both the water and the air to move a sailboat in almost any direction, and understanding the 'points of sail' are critical to being able to do this and propel their vessel efficiently. The position of the craft in relation to wind direction determines the amount of power the boat can gain.

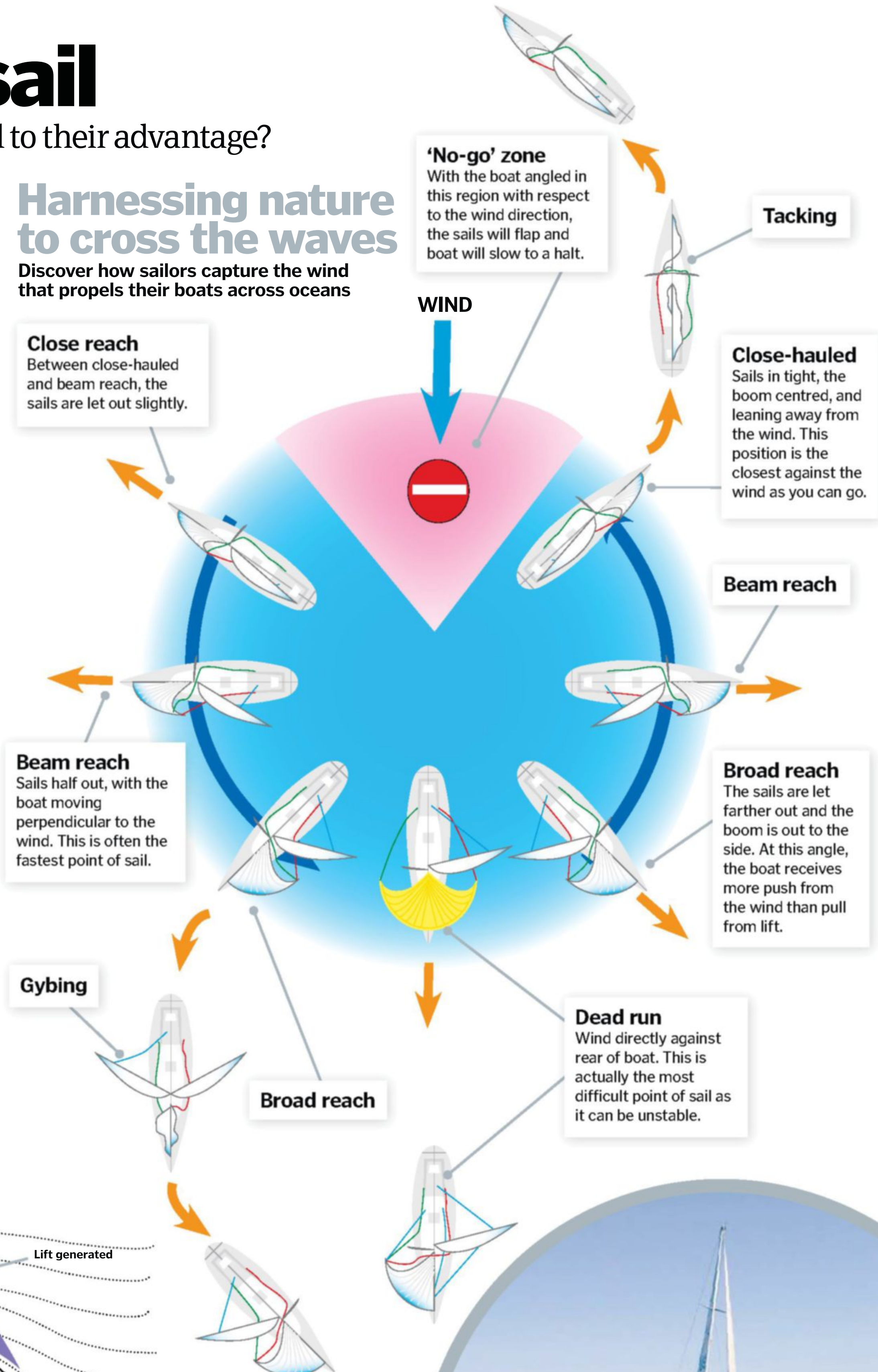
Generally, a sailboat consists of two sails – a mainsail and a jib. Beneath the boat is a lengthwise structure of wood or steel that runs along the base. This is called the keel and it is responsible for preventing the boat from tipping over, while also turning a rudder in the water that controls the direction of a sailing boat.

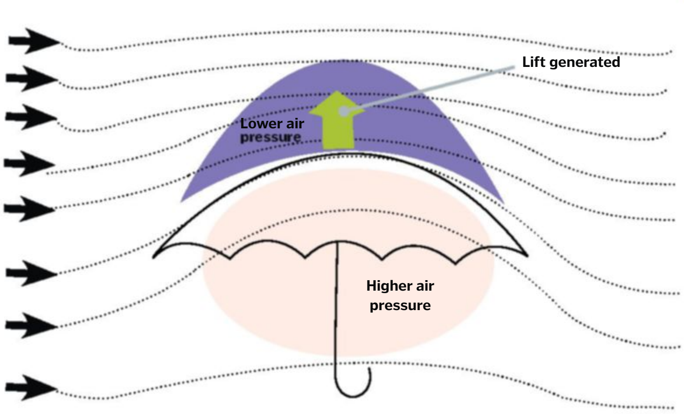
It is the sails of a boat that work to move the craft forwards by one of two methods. A sail sometimes works by catching the wind, but only when the boat is sailing downwind. For the rest of the time it functions in the same way as an aeroplane wing standing on its side. This means that rather than being blown along, the boat is moved more by the pull of the sail, in a similar way that an umbrella will be tugged out of your hand if there is fast wind moving over the top of it.

The design of a sailboat, in addition to the skill of the sailor, means the watercraft can move in every direction with the exception of the 'no go zone', which is directly into the wind. In this area the craft's sails are unable to generate enough drive to maintain forward momentum. Sailors are still able to move their boat upwind, but it requires patience and skill to zigzag from port to starboard side close-hauled.

Harnessing nature to cross the waves

Discover how sailors capture the wind that propels their boats across oceans





Sails work in a similar way to when an umbrella is pulled out of your hand by the wind

The points of sail all impact the way the boat sails and handles

Inside the Manhattan Project

In 1945, America unleashed the most powerful weapon the world had ever seen

The word atom means 'uncuttable', but in 1938 German scientists achieved the unthinkable. They split an atom into pieces, triggering an intensive period of research that would change the world forever.

Splitting the atom, or nuclear fission, was achieved by shooting neutrons at uranium. As the particles slammed into the atoms, their nuclei broke apart, creating lighter elements and releasing more neutrons in the process. If these neutrons could be harnessed, they could be used to split even more uranium atoms, triggering a chain reaction that could become powerful enough to be used as a weapon. And, as World War Two dawned, physicists were afraid that the Nazis would do just that.

Several scientists had fled fascism in Europe and arrived on American shores, and among them were Leo Szilard, Albert Einstein and Enrico Fermi. Szilard wanted to warn the president about the new discovery, but he was a junior researcher and needed a more senior scientist to back him up, so he asked colleague Edward Teller to take him to see Einstein, who then alerted President Theodore Roosevelt.

Roosevelt formed an advisory committee on uranium, but he was distracted by the war and it wasn't until 1941 that he really sat up and took notice. That was the year that Japan attacked Pearl Harbour, killing over 2,000 American soldiers in a brutal aerial ambush.

Headquartered in New York City and under the name of the Manhattan Project, Lieutenant General Leslie R Groves assumed control of atomic research. His team was given just $6,000 to investigate atomic warfare, and eminent physicist Enrico Fermi began work on the first phase. No one thought they would succeed.

Fermi had escaped Italy when he went to Sweden to collect his Nobel Prize; rather than return home, he fled to the US with his wife. As the Manhattan Project began, he focused his efforts on getting a nuclear chain reaction working, and with Szilard's help he built the world's first nuclear reactor in a squash court under the stadium at the University of Chicago.

To sustain a nuclear chain reaction, they needed to slow the neutrons down so that they could collide with more uranium nuclei and split them open. They did this by embedding uranium spheres in layer upon layer of graphite. Finally, in 1942, they succeeded in getting a chain reaction going, and the government started to pour money into research.

The army bought land in the desert at Los Alamos in New Mexico under the pretence that they needed a new demolition range. The new

facility was put under the command of physics professor Robert Oppenheimer, and the team started working out how much fuel they would need to build their bomb.

Uranium ore contains different isotopes of the radioactive element; the atoms of these variants have different numbers of neutrons. Most uranium is in the form of uranium-238, but to build a bomb the scientists needed uranium-235, so they needed a way to separate them. The calculations for how much fuel they would need were little more than estimates, but when Oppenheimer and his team asked for 200 kilograms of uranium (ten times more than they ended up using), President Roosevelt approved $500 million of extra funding.

The first separation devices for creating uranium fuel were designed by Ernest Lawrence at Berkeley, California. Known as calutrons, the machines were scaled-up mass spectrometers, which send atoms whizzing past a magnet. Uranium-235 is ever so slightly lighter than uranium-238, and the lighter an atom is, the more the magnet will bend its path, allowing the two to be neatly separated.

The process was painstakingly slow; each calutron structure could only produce ten grams of uranium-235 a day. So they built a dedicated facility called the Y-12 Uranium Enrichment Plant at Oak Ridge in Tennessee, which contained over 1,150 of them. There was no time to test the tech on a small scale, and when they first switched Y-12 on, its magnets reportedly pulled the nails out of the walls. However, once it was up and running, the plant attracted 75,000 workers, and by the end of the war Oak Ridge was the fifth largest town in Tennessee.

Calutrons alone weren't going to be able to produce enough uranium to build a bomb, so the Manhattan Project scientists employed a second enrichment method to generate even more fuel. Gaseous diffusion – developed in the UK in the 1940s – worked by combining uranium with fluorine to make uranium hexafluoride gas. This gas was then passed through a barrier studded with microscopic holes, barely large enough to allow the molecules through. The molecules containing the smaller uranium-235 isotope squeezed past slightly faster on average, allowing them to be collected. 300,000 square metres of the barrier were constructed at the K25 plant in Tennessee in 1943.

At its peak, the production of nuclear fuel for the programme was consuming a tenth of the energy produced in the US. And within the space of two years the Manhattan Project had expanded to become one of the largest scientific

"There was no time to test the tech on a small scale"

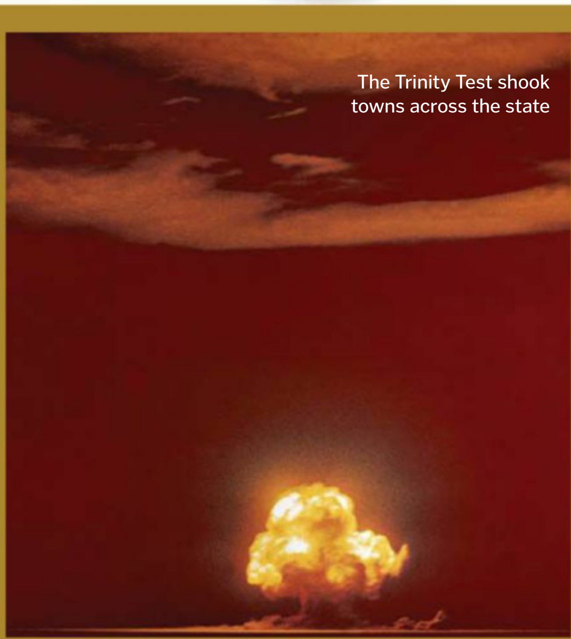
Uranium ore must be heavily processed to extract the right isotope needed to make a bomb

The first atom bomb

On 16 July 1945, the world changed forever. In the Trinity test, a 20-kiloton bomb known as 'The Gadget' was detonated in the Jornada del Muerto Desert in New Mexico, throwing a vast mushroom cloud into the air and turning the ground beneath to glass.

The Gadget was based on the same design as the Fat Man, the bomb that would later be detonated over the city of Nagasaki. It contained plutonium encased in explosives, designed to compress when it was triggered, kick-starting a nuclear chain reaction.

No one knew what would happen when an atom bomb went off, so soldiers were placed in the surrounding towns to help with an evacuation if it all went wrong. But the trial was a success, and less than a month later the bombs were dropped for real.



The Trinity Test shook towns across the state

The brains behind the bomb

Leo Szilard

Hungarian-born physicist Szilard was a close friend of Einstein and the catalyst of the Manhattan Project. He eventually led a petition against use of the bomb on cities.

Robert Oppenheimer

A theoretical physicist and head of the 3,000-strong team of scientists at Los Alamos, Oppenheimer later opposed the development of the hydrogen bomb.

Enrico Fermi

Awarded a Nobel Prize in 1938 for his work on radioactivity, Italian physicist Fermi led the beginning of the Manhattan Project. He constructed the first ever nuclear reactor.

Otto Hahn

German chemist Hahn discovered nuclear fission and was awarded a Nobel Prize. He was not a part of the Manhattan Project, but his science formed the basis of the bomb.

Edward Teller

Hungarian-American Teller led a team in the theoretical physics division at Los Alamos. A strong supporter of nuclear weapons, he is known as 'the father of the hydrogen bomb'.

Hans Bethe

Nobel Prize winner, Bethe was chief of theoretical physics at Los Alamos. He worked with Teller to develop the hydrogen bomb but later campaigned for nuclear disarmament.

Seth Neddermeyer

Neddermeyer was an American physicist and the mastermind behind the implosion design of the Fat Man atomic bomb that was dropped on the Japanese city of Nagasaki.

James Chadwick

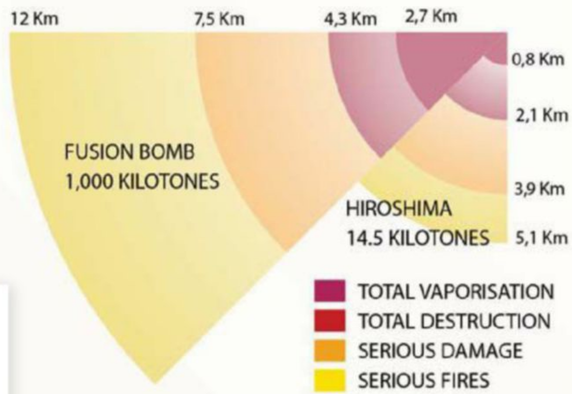
Chadwick was a Nobel Prize-winning English physicist who discovered neutrons. He led the British Mission collaboration with the Manhattan Project.

undertakings ever attempted, spanning several cities and employing tens of thousands of people from the areas of military, science and government. But the scientists still didn't know if their bombs would work.

Creating enough uranium for even one bomb was proving challenging enough, so there would be no extra fuel left over for a test, but in 1941, plutonium was discovered. This human-made radioactive element could be produced by irradiating uranium in nuclear reactors, and it could potentially fuel a second bomb. Scientists in Chicago designed reactors to generate plutonium, and over 60,000 construction workers were set to the task of building a new plant in the desert at Hanford in Washington.

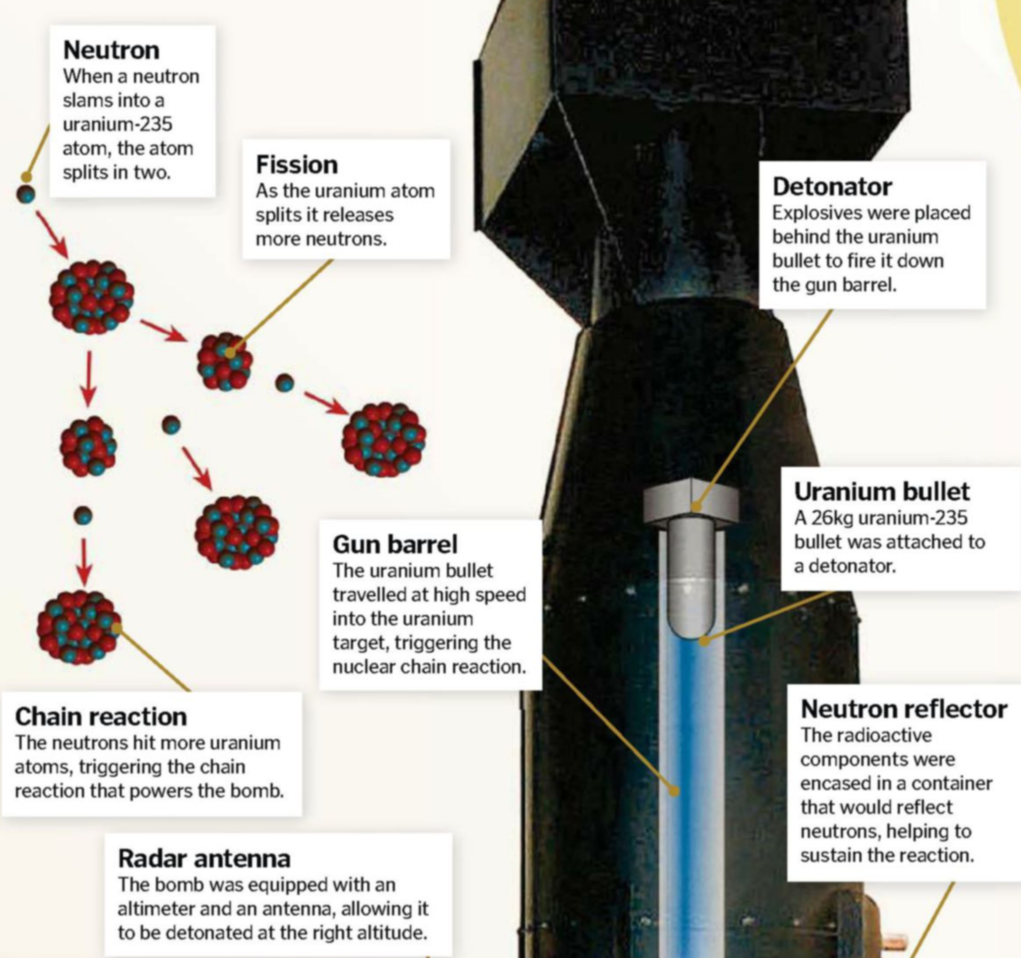
For the uranium bomb – later named Little Boy – the scientists were basing their design on a gun, firing one chunk of uranium into another to set off the chain reaction, but for the plutonium bomb they devised an outer shell of explosives that would detonate around a plutonium core. The shockwaves would push the plutonium atoms together, triggering the chain reaction.

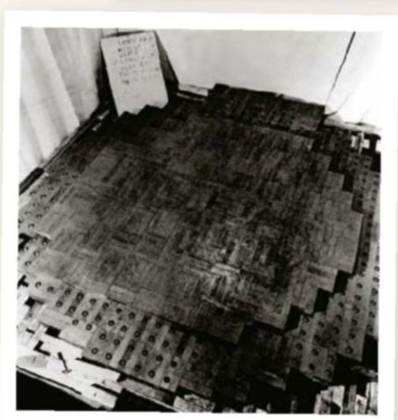
On 12 April, 1945, President Roosevelt died, and a month later, Nazi forces surrendered, but Japan refused to end the war, and America's project to develop their atomic bombs continued. President Truman made the decision to drop the bombs on 1 June that year, and in July they performed the first test on American soil, detonating a replica of the plutonium bomb - Fat Man - and releasing a blast equivalent to 20,000



The Little Boy

The bomb dropped on Hiroshima was a 'gun-type' design



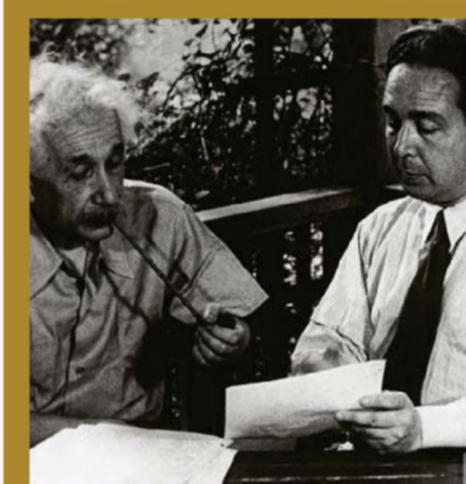


The first nuclear reactor under construction in a squash court in Chicago

Trying to stop the bomb

Physicist and inventor Leo Szilard had been the catalyst for the start of the Manhattan Project, but by 1945 he and many other scientists had become seriously concerned about the bombs that they'd helped to create. Szilard penned a petition to the president which read, "Atomic bombs are primarily a means for the ruthless annihilation of cities… a nation which sets the precedent of using these newly liberated forces of nature for purposes of destruction may have to bear the responsibility of opening the door to an era of devastation on an unimaginable scale."

The petition was signed by 70 scientists working on the Manhattan Project, but in April of 1945 President Roosevelt died. Szilard didn't know how to get the message to the new president, and Truman never saw it before the bombs fell.



Leo Szilard with Albert Einstein before the start of the Manhattan Project

Nagasaki before and after the atomic bomb was detonated

tons of TNT. This was right at the upper end of their estimates, and it turned the desert sand into glass.

On 6 August 1945, Paul Tibbets boarded the Enola Gay, named after his mother, and flew over Hiroshima with Little Boy. It had taken 120,000 people and over $2 billion to develop the atomic bombs, and within moments 90 per cent of the city was flattened and 150,000 people were killed by the blast or subsequent radiation sickness. Two days later, Fat Man was detonated over Nagasaki, killing a further 75,000. Japan surrendered on 15 August 1945.

Oppenheimer, who led the Manhattan Project said, "We knew the world would not be the same. A few people laughed, a few people cried, most people were silent. I remembered the line from the Hindu scripture, the Bhagavad-Gita. Vishnu is trying to persuade the prince that he should do his duty, and to impress him takes on his multi-armed form and says, "Now I am become Death, the destroyer of worlds." I suppose we all thought that, one way or another."

"We knew the world would not be the same" – Robert Oppenheimer

Nuclear power now supplies over ten per cent of the world's energy

The Manhattan Project's legacy

After the end of World War Two, America continued to conduct atomic tests. The world had never before seen a weapon capable of such rapid and complete destruction, and as the atomic age dawned, several countries joined the nuclear arms race, stockpiling their own weapons to deter attacks from other nuclear states.

The Soviet Union, using information leaked by spy Klaus Fuchs, tested their atom bomb for the first time in Kazakhstan in 1949. The UK detonated the Hurricane in 1952, France joined in with Blue Gerbil in 1960, and China did their first test in 1964.

America also rushed to develop the hydrogen bomb, which they detonated in 1952 in the Pacific Ocean, completely vapourising the island of Elugelab. And, using more information from Fuchs, the Soviets designed their own, culminating in a 58 megaton blast in 1961.

In 1968, the US, USSR and UK agreed to a Non-Proliferation Treaty to limit the spread of nuclear weapons. They also encouraged the sharing of peaceful nuclear technology across the world, helping positive new developments like nuclear power and nuclear medicine to reach as many people as possible.

Close up of the tubes that fed uranium into the Hanford reactor

Milan Cathedral

Italy's spectacular Gothic masterpiece took almost six centuries to complete

In the heart of Milan stands the fifth largest Christian church in the world. Known as Duomo di Milano in Italian, it was commissioned by Archbishop Antonio da Saluzzo in 1386 as a replacement for the old Basilica of Santa Maria Maggiore.

The new cathedral was originally going to be constructed from terracotta brickwork, but the lord of Milan, Gian Galeazzo Visconti, decided pink-hued white Candoglia marble would create a grander impression. A workforce of architects, sculptors and labourers travelled from all over Europe to work on the project, and a network of canals was dug to transport the marble from the Candoglia quarries to the construction site.

By 1560 much of the nave was complete and the first spire had been sculpted, but the arrival of a new archbishop saw the plans change. Influenced by the Catholic Reformation, Carlo Borromeo and his architect, Pellegrino Pellegrini, opted to subdue the Gothic look for a Renaissance appearance while they continued to develop the interior and design a new façade. However, when architect Carlo Buzzi was put in charge in the 17th century, he reverted back to the Gothic style and added the iconic main spire and its Madonnina statue.

The building now stood at an impressive 108.5 metres, but the façade still remained that of the original basilica. Politics and a lack of money had stalled the project, and so it was down to Napoleon Bonaparte, the soon-to-be ruler of Italy, to order for the new façade to be completed in 1805. Allied bombing during WWII caused yet more delays, but in 1965 the finishing touches were finally added. 78 different architects had worked on the cathedral over six centuries.

Restoration work

Ever since the cathedral was completed renovation has been ongoing. First, the main spire became unstable and had to be remounted on a concrete platform and reinforced with stainless steel, and over the last 20 years, 25 more spires have needed similar attention. Several of the interior pillars have also been repaired due to instability caused by subsidence, and in 1972, restoration of the façade began to repair damage done by smog and pigeon droppings. Once the marble had been cleaned, a water-repellent coating was applied and electrical pigeon deterrents installed, but a further period of restoration was needed in 2003. Laser scanning was used to identify areas of deterioration, and a five-year-long project was launched to replace marble blocks and ornamentation.

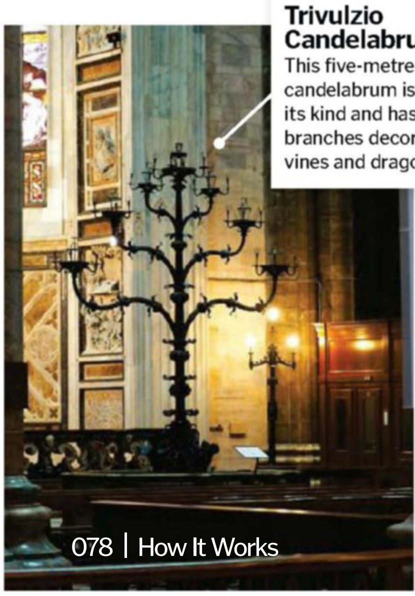
The Madonnina statue is 4.16 metres tall and gilded with 6,750 sheets of gold foil

Spires
The 135 spires and pinnacles are a typical feature of Gothic architecture and symbolise reaching for the heavens.

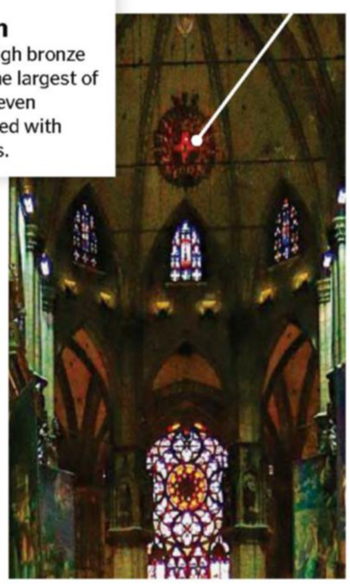
The Madonnina
The gilded copper statue of the Virgin Mary was sculpted by Guiseppe Bini and marks the cathedral's highest point.

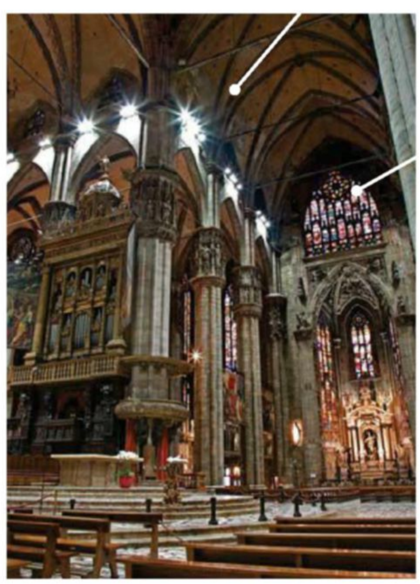
Red bulb
Above the altar, a red light marks the spot where one of the nails of Jesus' crucifixion was allegedly placed.

Interior
Five broad naves are separated by 52 columns, each almost 25m tall and decorated with statues.



Trivulzio Candelabrum
This five-metre-high bronze candelabrum is the largest of its kind and has seven branches decorated with vines and dragons.





Stained glass windows
The windows are a mixture of 15th-century historiated stained glass and 19th-century enamel painted glass.

Roof terraces

Roof terraces
From here you can get a close-up view of the spires and enjoy a breath-taking view of Milan and the Alps.

Statues
The cathedral is decorated with 3,400 statues and over 700 figures found in the marble high reliefs, the most of any building in the world.

The Duomo Organ

The magnificent organ of the Duomo di Milano is one of the largest organs in the world and was built in 1938 by two of the most significant families of 20th-century organ-makers: the Mascioni firm of Cuvio (Varese) and Tamburini of Crema. It ranks second in Europe for the number of pipes, with 15,800 in total ranging from over nine metres to just a few centimetres long. When it was first installed it consisted of seven separate organs scattered around the cathedral. However, in the mid-1960s it was dismantled while the cathedral was being repaired, and in 1986 it was unveiled in its new position behind large windows above the sacristies.

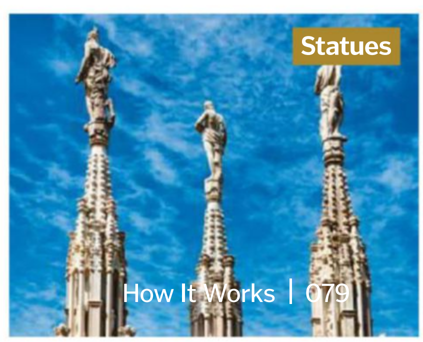
Façade
Napoleon Bonaparte ordered for the façade to be completed on the eve of his coronation as King of Italy in 1805.

Doors
The five doors were made from 1840-1965 and are decorated with intricate carvings and bronze reliefs.

Spires

Doors

Façade



Statues

How to build a Viking settlement

The Viking settlement of Jorvik later became the city of York

Scandinavian seafarers took Europe by storm in the Viking Age

Towards the end of the 8th century Norsemen left their native Scandinavia in search of new land and riches and set sail in their longboats across the North Sea. When they reached Britain, their main objective was to steal from the locals, earning themselves the 'Viking' name, which is Old Norse for 'a pirate raid'. However, as well as being fearsome warriors, they were also skilled settlers and soon decided to conquer these new lands as well as raid them. They battled their way through much of northern England, taking control of several Anglo-Saxon kingdoms, until an agreement was reached that divided the country roughly in half. The east became known as Danelaw, the land of the Vikings, while the west belonged to the Anglo-Saxons.

The small settlements established by the Vikings quickly expanded into thriving centres for trade, and many are still there to this day. Dublin, York and Derby are all cities that were founded by the Viking settlers, and they eventually conquered other parts of Europe, too, with attacks reaching as far as the Mediterranean and the Iberian region.

"When they reached Britain, their main aim was to steal from the locals"

Vikings on the move

Discover how to conquer new lands and establish a prosperous Viking town

1 Vikings assemble

Gathering plenty of manpower and a large fleet will make it much easier to take and secure a settlement in a foreign country. Most Viking armies had between 1,000 and 2,000 men and up to 100 longships.

2 Location, location, location

Carrying out a few raids along the coast will allow you to scout out the best locations for your new home. Regions that have been settled for many years are ideal, particularly old Roman towns.

3 Build a base camp

Your ships can be dragged ashore and used to build outer defences for a longphort, or 'ship camp', on the coast. This can act as a base for further raiding inland or later be developed into a more permanent settlement.

4 Raiding and pillaging

Monasteries are a good target for raids as they are undefended and full of treasures, but if you do meet some resistance then you can fight off the locals with your longsword and axe.

5 Time to trade

To ensure your settlement prospers, establish it as a trading hub for the region, selling items such as fur, wool, fish and even slaves. Eventually, Viking trading networks will stretch across Europe and into central Asia.

6 Get ready to defend

Your new settlement will be under constant threat from rival Vikings and native Anglo-Saxon armies, so good defences are key. Establishing a royal dynasty will also help ensure a stable succession of future rulers.

Pompeii casts

Discover how the victims of a volcanic eruption have been preserved

On 24 August 79 CE, Italy's Mount Vesuvius erupted with a violent explosion of lava, rock and ash, sending a cloud of debris 32 kilometres into the air. The nearby town of Herculaneum was soon hit with a scolding pyroclastic surge of volcanic materials, instantly incinerating everyone in its path, while ash and pumice rained down on the neighbouring city of Pompeii. Some of the city's residents managed to flee in terror, but others stayed in their homes hoping the danger would pass. The next morning, a second pyroclastic surge ploughed into the city, suffocating those that remained with toxic volcanic gas and burying them in mud and ash.

Pompeii was lost for the following 1,500 years before being rediscovered in 1599, and after another 150 years a wide-scale excavation of the city began. As archaeologists were digging through the volcanic debris, they noticed distinct cavities in the lava, some of which contained human bones. They soon realised that these were perfect moulds of the dead, left behind after their bodies had decomposed. At first they couldn't work out how to preserve them, but following his appointment in 1863 the director of the excavations, Giuseppe Fiorelli, came up with an ingenious solution. He directed the archaeologists to pour plaster into the cavities so that it would set to form exact replicas of the victims at the moment of their death.

> *"Pompeii was lost for 1,500 years until its rediscovery in 1599"*

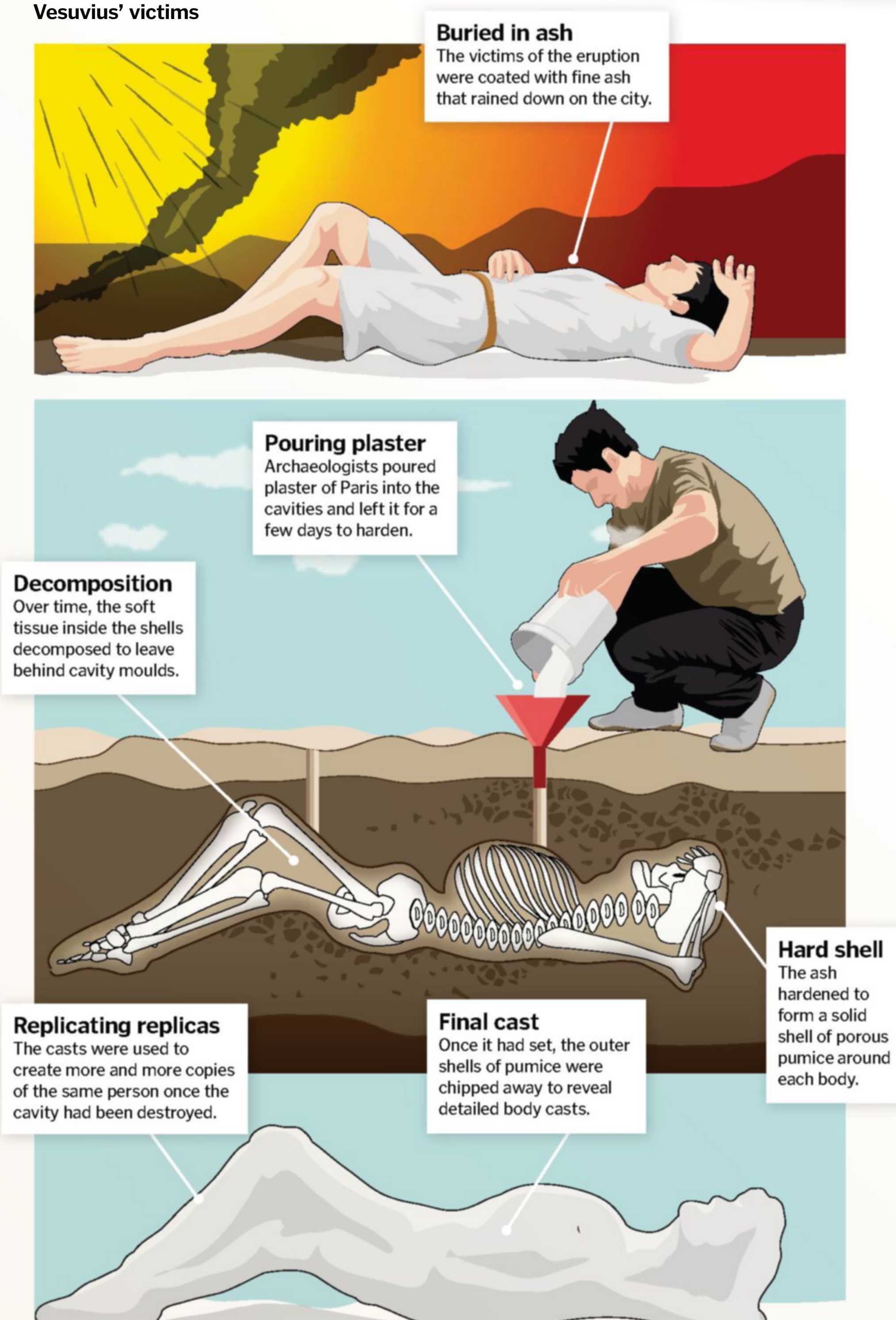
It was a difficult process, as the plaster had to be mixed to exactly the right consistency to ensure that it was thick enough to support the skeleton but not so thick that it destroyed the fine details of the mould. When they chipped away at the surrounding rock, the final casts were revealed, some featuring intricate details of the victims' hairstyles, clothing and facial features.

Of the 1,150 bodies discovered at Pompeii, around 100 have been preserved in this way, providing a unique insight into the life and death of the city's residents. Nowadays, modern techniques like 3D scanning have even enabled scientists to create digital images of what the victim's actually looked like, truly bringing them back to life almost 2,000 years after they met their cruel fate.

The famous preserved Pompeii 'bodies' are actually plaster casts of the cavities left by the victims

Restoring the dead

Discover how archaeologists created lifelike casts of Vesuvius' victims



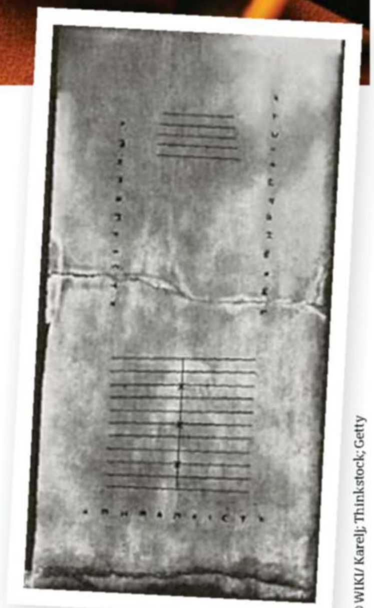
The word 'abacus' is Latin, but it's derived from the Greek word *abax*, which means 'board covered with sand'

Abacus

The ancient calculators that made complex sums simple

Before the invention of the written Hindu-Arabic numerical system that is still used worldwide today, ancient mathematicians performed complex calculations using an abacus. The device is thought to have evolved from the system of columns and markers used on Babylonian counting boards around 300 BCE, but it first appeared as it does today in China around 1200 CE.

The simple counting tool features a series of beads that can be moved up or down wires to represent numbers that are too large to be counted on the human hand. These days they have mostly been rendered obsolete by digital calculators, but they are still used by some shopkeepers in Asia to calculate each customer's bill, as well as by the visually impaired.



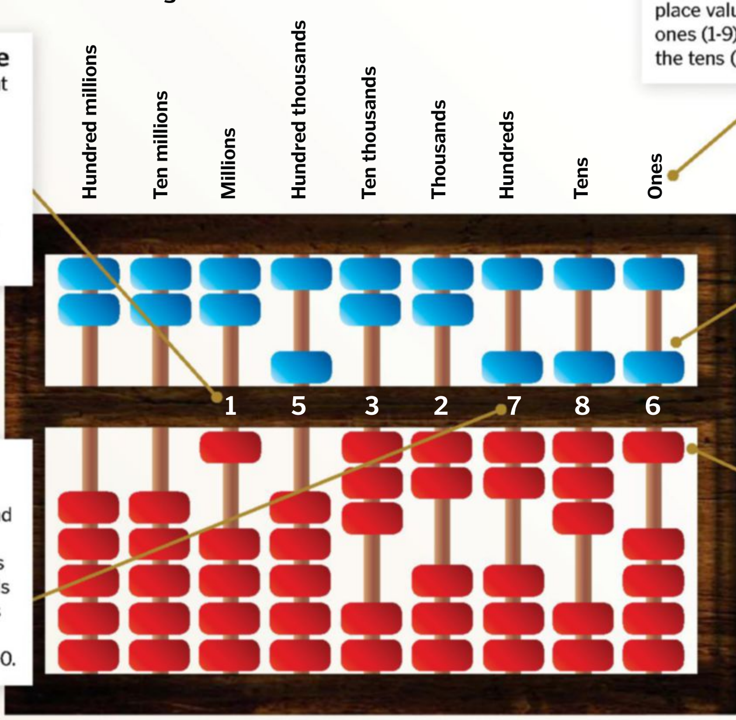
The Salamis Tablet, the oldest counting board ever discovered, is an early version of the abacus

Ancient arithmetic

Learn how to count using an abacus

Total value
The beads that are pushed against the central bar represent the final number read from left to right.

Place value
Each column represents a place value, starting with the ones (1-9) on the right, then the tens (10-99) and so on.



Five-unit beads
Each bead in the top section represents the numerical value five, and is counted by pushing it down.

Individual numbers
A five-unit bead and two one-unit beads in the hundreds column equals 700 because (5+2)x100=700.

One-unit beads
Each bead in the bottom section represents the numerical value one and is counted by pushing it up.

Deadly cosmetics

Discover some of history's most ill-advised beauty secrets

Lead makeup

During the Roman Empire, and in England until the 19th century, women would whiten their faces with a lead mixture called Ceruse. The resulting poisoning would cause blemishes, hair loss and even death.

Arsenic Complexion Wafers

During the late 19th century arsenic was known to be poisonous, yet some believed that consuming small amounts was a good way of removing freckles, pimples and other facial marks.

Belladonna eyedrops

The poisonous plant deadly nightshade (*Atropa belladonna*) was used by women to dilate their pupils and give them big, beautiful eyes, but it could also cause blindness.

Mercury rouge

A bright red and highly toxic mercury sulphide mineral called cinnabar was used as a blusher for thousands of years but proved fatal when it was absorbed into the bloodstream.

Radium skin cream

Following its discovery in 1898, radium was heralded as a revolutionary beauty secret and added to all sorts of cosmetics, until later studies proved it to be deadly.

Special offer for readers in **North America**

4 FREE issues

When you subscribe*

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0)344 848 2852**

Online at **https://www.myfavouritemagazines.co.uk/hiwusa**

OFFER EXPIRES 30 Sept 2017

***Terms and conditions** This is a US subscription offer. 4 free issues refers to the USA newsstand price of $9.99 for 13 issues being $129.87, compared with $87.08 for a subscription. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magtandc. Offer ends 30 September 2017

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@futurenet.com

MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Katy Sheen

Katy studied genetics at university and is a former **How It Works** team member. She now works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

Why do they celebrate Day of the Dead in Mexico?

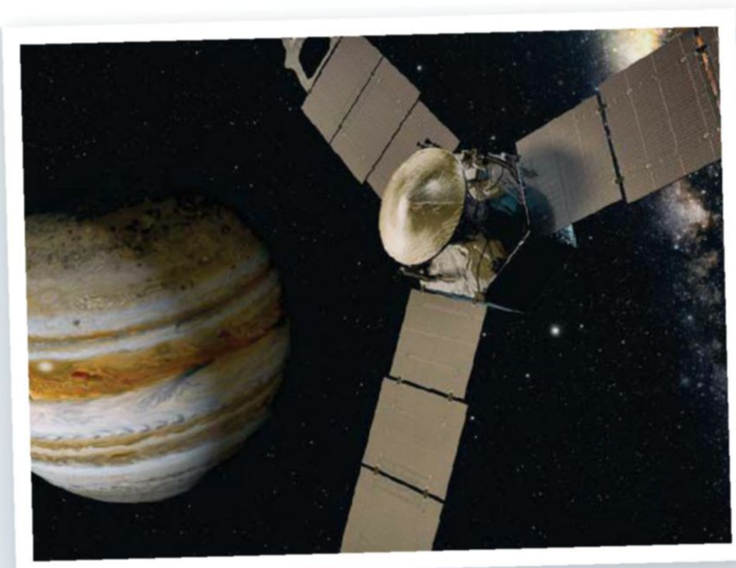
Sarah Copeland

Day of the Dead, or Día de Muertos in Spanish, is a public holiday celebrated in Mexico every year on 2 November. It dates back to the Aztec period when people believed that they could encourage the spirits of their deceased loved ones to return by offering them gifts. When the Spanish arrived in Mexico the holiday was moved to coincide with the Roman Catholic All Souls Day, and it is now seen as a day for honouring the dead with family gatherings, food and drink. **JS**

How does a 'gravity slingshot' work exactly?

Lisa Heitz

As a spacecraft approaches a planet it speeds up under the force of gravity, and as it gets further away it slows down. But planets are orbiting the Sun, so if a spacecraft catches up to a planet and moves in the same direction around the Sun, it is able to steal a tiny bit of its acceleration. When the spacecraft breaks away, it will be going much faster than it was when it arrived. **LM**

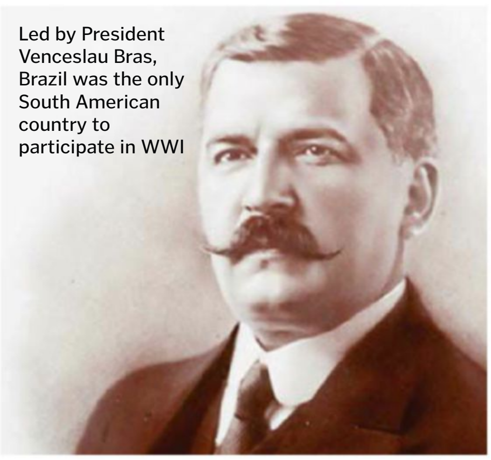


Certain species of frog and toad play dead to evade predators

Why do animals play dead?

Li Yung

■ Playing dead, a behaviour known as thanatosis, has been observed in several species in the animal kingdom. In most cases, such as that of the American opossum, it is a form of defence from predators. Not only does it help the creature evade detection, but it also serves as a warning not to eat them because if they are already dead, they may harbour dangerous bacteria. Alternatively, thanatosis can be used to attract scavenging species as prey or, in the rare case of the male nursery web spider, help induce mating by encouraging the female to drag them to their nest. **JS**



Led by President Venceslau Bras, Brazil was the only South American country to participate in WWI

Why did Brazil enter World War I?

Terry Landing

■ At the beginning of World War I, Brazil held a neutral position on the conflict. However, the war interrupted trade channels that Brazil held with Germany, and instead strengthened its ties with the United States. Public opinion in Brazil gradually steered towards supporting the Allied forces, and when German submarine warfare destroyed a Brazilian vessel in October 1917, the country took action. Brazil declared war on the German Empire on 26 October 1917. **KS**

What are the differences between clementines, satsumas, tangerines and mandarins?

Lee Connelly

■ All four of these fruits are varieties of the species *Citrus reticulata*, sometimes known as loose-skin oranges or 'easy-peelers'. It is thought that the mandarin was the original fruit, from which the three other easy-peelers were bred. However, the differences between these citrus fruits are subtle, so the names are often used interchangeably. Clementines are usually seedless and sweet, while tangerines are more acidic, have more seeds and are trickier to peel. Satsumas are the simplest to peel, low on seeds and have a more delicate flavour. Tangerines are traditionally darker in colour than mandarins, but there is very little difference between the fruits themselves. **KS**

Easy-peelers can be bred to have fewer seeds, making the varieties even harder to distinguish

When was the unicycle invented?

The history of the unicycle is a little unclear, but it is thought that the unusual vehicle emerged shortly after the penny-farthing bicycle in the late 1800s, when skilled cyclists began demonstrating that they didn't need the bike's smaller wheel to balance. **KS**

Can you get potassium poisoning from bananas?

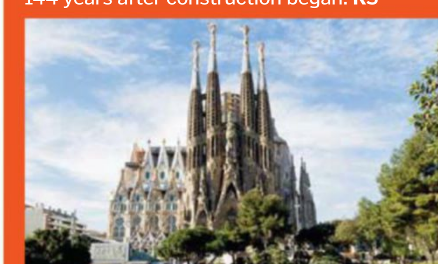
For potassium levels in your bloodstream to reach potentially lethal levels, you would have to eat about 250 bananas in one sitting, making it highly unlikely! **AC**

How do spy planes avoid radar systems?

Radar works by sending out radio waves and then detecting any that get reflected back by bouncing off a surface. Spy planes are painted or made with materials that absorb the radar signal, meaning less of it bounces back, and they have stealthy shapes that deflect the radar signal away from the radar station. **TL**

Why has it taken so long to finish the Sagrada Familia?

Architect Antoni Gaudi designed the Sagrada Familia to be incredibly ornate, incorporating delicate arches, spires and ornamental features throughout. It is set to be completed in 2026, 144 years after construction began. **KS**



Decompression chambers counteract the effects of decompression sickness in divers

How do decompression chambers work?

Penny Walters

Hyperbaric chambers work by reproducing high atmospheric pressure to reverse the symptoms of decompression sickness ('the bends'). When scuba diving, nitrogen from a diver's air tank dissolves into their bloodstream. Ascending too quickly causes a rapid pressure drop and bubbles of nitrogen to form, a bit like when you open a fizzy drink. Symptoms can include muscle pain and fatigue. By subjecting a person suffering from the bends to increased pressure, the nitrogen in their blood is forced back into solution, relieving the symptoms. By gradually reducing the pressure inside the chamber the patient is brought back to normal air pressure. **AC**

Energy-saving lightbulbs take some time to reach full intensity

Why do energy-saving bulbs take time to 'warm up'?

Julian Scalari

Energy-saving lightbulbs light up gradually since it takes time for the mercury inside the bulb to fully vaporise. The bulb contains a small amount of mercury in liquid form at room temperature. When you switch on the light, causing an electric current to run through the bulb, the heat converts the mercury to a gas, which emits ultraviolet radiation. The phosphor coating the bulb casing then absorbs this ultraviolet light, re-emitting it as visible light. **AC**

Who invented chess?

Chess' ancestor is a 6th century Indian game called chaturanga. Over centuries many people played different versions of chaturanga and it gradually evolved into modern chess, so it has many inventors. **TL**

What's the best way to get rid of a stitch?

Just breathe. A stitch is a cramp in the diaphragm – the sheet of muscle that sits between your lungs and your abdomen. Steady, deep breaths and some stretching should help to sort it out. **LM**

Can sharks swim backwards?

Unlike most other fish, sharks cannot swim backwards, but some species can 'walk' backwards. The epaulette shark, for example, can use its fins to pull itself along the seabed in reverse. **JS**

Why do comets have tails?

The Sun creates a stream of particles called solar wind, which blows material away from comets, creating their tails. One tail is made of tiny fragments of dust, the other of electrically charged particles, and sometimes there's a third tail made from sodium. **LM**

Milk is deliberately curdled to produce the curds needed to make cheese

Why does milk curdle?

George Edison

Milk contains tiny casein molecules arranged in structural spheres called micelles. These interact with water but float separately in the liquid, repelling other micelles with their negative charge, which helps them to stay mixed into the milk. As milk gets old, it starts to go sour because of acids produced by microbes. These acids neutralise the charge of the micelles, causing them to clump together. The result is that the milk starts to split, leaving blobs of fat and protein called curds and a watery liquid known as whey. **LM**

How does nail polish remover work?

Hannah Tompson

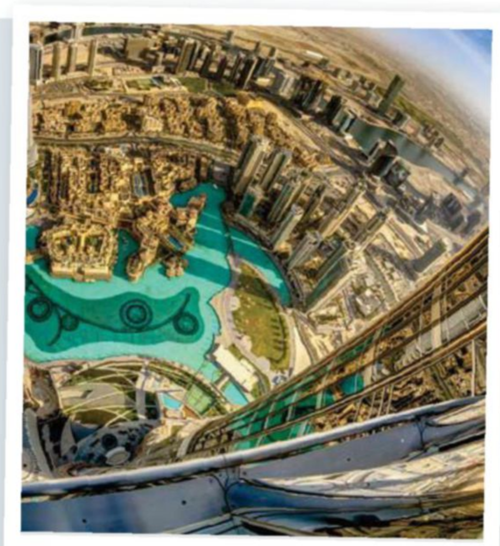
Nail polish remover is a solvent, usually acetone or acetate, which takes off nail polish by getting in between the polymer chains in the polish. Once these chains are separated, the resulting solution can be easily wiped off. **AC**

US choclate maker Hershey's process for making milk chocolate is a closely guarded secret

Why does British and American chocolate taste so different?

Chuck Wilson

The taste of chocolate is determined by the amount of cocoa it contains, how long the chocolate was mixed for, the flavour of the milk used, and any additional ingredients that are added. These factors can differ in American and British chocolate, giving them their distinctive individual tastes. **JS**



How did they build the Burj Khalifa?

Jeremy Clarke

This 829.8-metre-high skyscraper (the world's tallest building) was built in Dubai between 2004 and 2009. Construction began with digging a hole to lay the foundations, needing over 100,000 tons of concrete and steel piles driven into the ground to support the structure. Workers then built the central core, which supports the structure and contains elevators. As the core grew, with giant cranes lifting materials into place, workers on the levels below built outwards, adding supporting walls, floors and cladding. **TL**

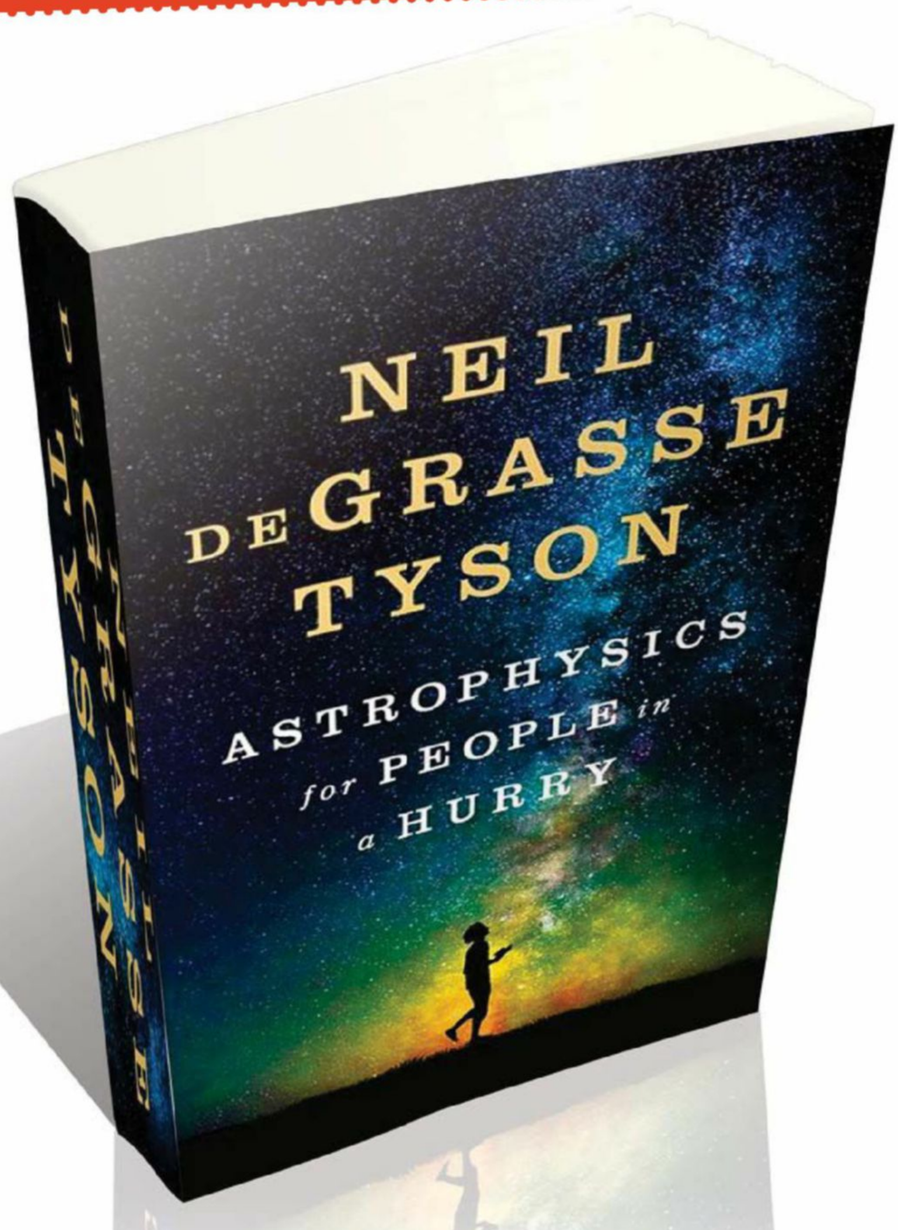
Why did Prohibition start in the US?

Susana Delgado

In the US, popular 'temperance' movements that opposed alcohol became powerful by the early 20th century. Some religious groups saw drunkenness as sinful. Others worried about crime and the social and health problems that alcohol caused. It was also thought that drinking might have harmed America's effort in WWI, so alcohol was prohibited in 1919. Yet rather than cutting crime it led to gangsters supplying booze illegally and making a fortune. It was abandoned in 1933 as a failed experiment. **TL**

BOOK REVIEWS

The latest releases for curious minds



Astrophysics for People in a Hurry

A quick look at the universe

- Author: **Neil DeGrasse Tyson**
- Publisher: **W W Norton & Co**
- Price: **£14.99 / $18.95**
- Release date: **Out now**

Shows like *The Big Bang Theory* have helped bridge the gap between science and popular culture in recent years and turned scientists like Neil DeGrasse Tyson into names known around the world. And with good reason – DeGrasse Tyson is one of the foremost astrophysicists in the world and has a talent for communicating complex ideas in a way that is not only easy to understand for even the most uneducated listener, but is also incredibly arresting as well.

It's fair to say, then, that we opened *Astrophysics for People in a Hurry* with high expectations. At just over 200 pages, the book doesn't have all that much space to cover such an intensely complex topic, but DeGrasse Tyson manages it with aplomb. In fact, this collection of essays (previous published between 1997 and 2007 in *Natural History* magazine) toes the line between entertainment and interest brilliantly, never getting too bogged down in fine detail.

There are certainly parts – especially in the first chapter – where we had to go back and read through sentences again to fully understand their meanings. Frankly, however, we would expect nothing less when someone is explaining the science of the Big Bang and the quarks, bosons and other particles involved in it, in less than 18 pages. As we said, these are intensely complex subjects.

What the book does so well, though, is intersperse this high-level science with stories from DeGrasse Tyson's childhood, interesting facts about the world, and even fart jokes. And that's not something we were expecting to say in this review. But that's part of this book's magic. While the focus is, of course, astrophysics, the book meanders through various scientific topics as it discusses this.

The last two 'chapters' are a particular highlight, discussing the size of the universe and the likelihood of alien life being able to find us, let alone communicate with us, in the vastness of space. There are lessons here that deserve attention; that DeGrasse Tyson conveys them without preaching is a masterstroke. It's a fine end to an excellent collection and well worth your time – even if you're in a hurry.

YOU MAY ALSO LIKE…

A Short History of Nearly Everything

Author: **Bill Bryson**
Publisher: **Black Swan**
Price: **£9.99 / $18**
Release date: **Out now**

Considerably larger than DeGrasse Tyson's work but also more wide-ranging, this amusing yet informative book covers everything from the Big Bang to the first human civilisation.

Death by Black Hole: And Other Cosmic Quandaries

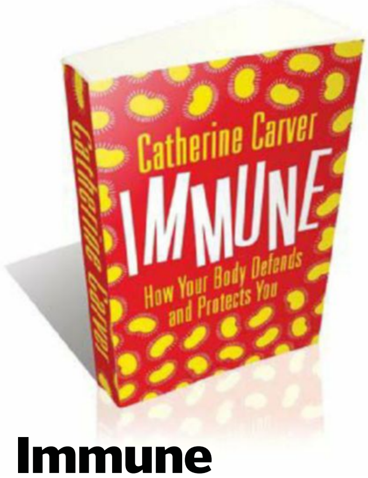
Author: **Neil DeGrasse Tyson**
Publisher: **W W Norton & Co**
Price: **£12.99 / $15.95**
Release date: **Out now**

Another collection of DeGrasse Tyson's essays, this explores topics including the night sky's authenticity in movies and – you guessed it – black holes.

Everything All at Once

Author: **Bill Nye**
Publisher: **Rodale Press**
Price: **£21.01 / $26.99**
Release date: **Out now**

America's famous Science Guy aims to help you unleash your inner nerd and look at the world in a different way. The aim is to achieve great results just by changing the way you think.

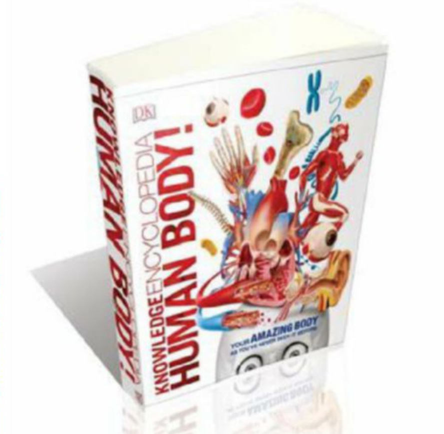


Immune

How your body defends and protects you

- Author: **Catherine Carver**
- Publisher: **Bloomsbury Sigma**
- Price: **£16.99 / $27**
- Release date: **21 September 2017**

Exploring the depth of a scientific topic while remaining entertaining and enticing to a wider audience is a delicate tightrope to walk – but it's one that Catherine Carver does brilliantly in *Immune*. The book is dedicated to explaining our body's intricate immune system, its brilliance and its pitfalls, from our highly capable 'adaptive assassins' – so often our silent protectors – to our immune network's inability to recognise tumors. Carver, a trained medical doctor and research scientist, has ably deconstructed the often off-putting complexities of biology with her witty and imaginative prose.



Knowledge Encyclopedia: Human Body!

An illustrated guide to your insides

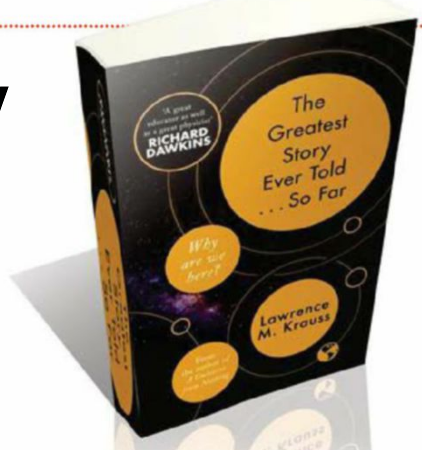
- Author: **N/A**
- Publisher: **DK**
- Price: **£18.99 / $24.99**
- Release date: **Out now**

It will come as a surprise to no one that the human body is incredibly complex. Home to a multitude of organs busily performing a diverse range of functions, the intricate machinery that keeps us running is still poorly understood. In *Human Body!*, DK presents a readily accessible guide to fill in the blanks and help educate younger readers on the components, cells and organs that comprise us. Well-drawn 3D illustrations play a key role, reinforced by diagrams, infographics, tables and text to present a vast amount of information in a welcoming format. Recommended for budding scientists.

The Greatest Story Ever Told… So Far

How humanity came to understand the universe

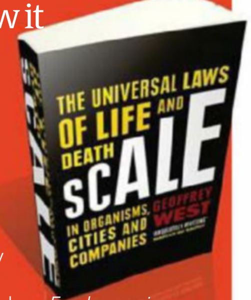
- Author: **Lawrence M Krauss**
- Publisher: **Simon & Schuster**
- Price: **£20 / $15.79**
- Release date: **Out now**



From critically acclaimed author Lawrence Krauss comes a boldly titled book that showcases both the wonder of physics and his expert ability to convey it simply to a non-expert audience. Some of the chapters are, at the very least, tailored for an enthusiast of the physical laws, but that should not dissuade those who are interested in investigating humanity's place in nature. In 23 chapters Krauss guides us through the features of the universe that govern our very existence and reveals the questions that remain a mystery to our greatest minds, which are bound to intrigue.

Scale: The Universal Laws Of Life And Death In Organisms, Cities And Companies

The scale of life as we know it

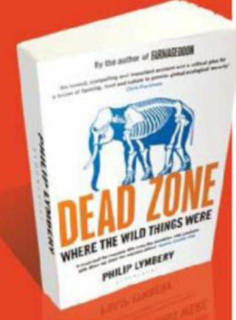


- Author: **Geoffrey West**
- Publisher: **Orion**
- Price: **£25 (approx. $32.50)**
- Release date: **Out now**

Testing the strength of a theory tends to involve applying it to as wide a subject matter as possible. Physicist Geoffrey West takes this and runs with it, applying the question of why humans live as long as they do to businesses, socioeconomics and much more. The resulting book is a less deadpan *Freakonomics*. While his conclusion is clear from the outset – all living organisms are, to a degree, scaled down versions of each other – in truth this is a starting point for what turns out to be an astonishing book, possibly the most memorable one you'll read for a while.

Dead Zone: Where The Wild Things Were

The price nature pays

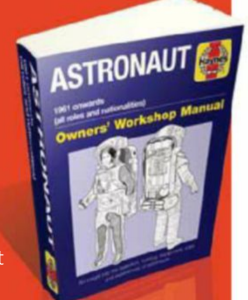


- Author: **Philip Lymbery**
- Publisher: **Bloomsbury**
- Price: **£12.99 / $18**
- Release date: **Out now**

As the human population increases and natural resources become scarce, the animal kingdom sadly has to bear the brunt of the negative consequences. More and more species are becoming endangered all the time, and it's hard to see where it will all stop. Philip Pymbery paints an aptly bleak picture, discussing in depth a number of species now in dire straits while detailing what can be done to save them. It might leave you with a feeling of helplessness, but that's no reason to steer clear. This comes packaged with much critical praise, and you will see why upon turning its pages.

Astronaut 1961 Onwards: Owners' Workshop Manual

Spaceman revisited



- Author: **Ken MacTaggart**
- Publisher: **Haynes**
- Price: **£22.99 / $36.95**
- Release date: **Out now**

We're a huge fan of the Haynes manuals here at **How It Works**, but surely they're running out of subject matter? Apparently not, as denoted by this latest installment in the series. Focusing on the classic astronaut suit, reading this is akin to taking a journey through time and space, from the earliest science fiction to the advances that made the Moon landings possible, and the subsequent successful attempts to achieve this. Haynes has long mastered the art of appealing to all ages, and the same feat has been achieved here. One for the budding spacefarer in the family.

BRAIN GYM
GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

N	P	O	S	L	L	W	D	T	S	S	E	V	S	Q
B	O	K	O	I	T	Y	E	S	S	Y	O	E	E	M
M	T	K	C	Y	U	H	F	U	U	N	M	O	O	N
C	X	A	I	P	I	N	E	N	R	T	O	M	A	B
O	E	L	A	A	P	A	Y	A	T	H	U	R	N	F
P	B	B	L	N	J	K	E	M	T	E	D	G	T	I
U	A	V	M	G	H	A	L	I	Y	S	O	N	H	I
L	L	C	E	O	U	S	L	X	H	I	W	I	R	E
S	O	T	D	L	O	V	A	T	F	S	A	L	O	P
A	R	H	I	I	I	X	R	W	T	E	U	I	P	M
R	T	R	A	N	E	A	B	X	R	R	I	A	O	O
C	S	W	P	U	E	L	A	U	O	A	O	S	C	P
N	A	T	T	A	H	N	A	M	I	Q	C	G	E	A
G	G	I	M	K	L	R	E	D	A	E	L	H	N	E
I	N	T	R	A	V	E	N	O	U	S	P	K	E	T

FIND THE FOLLOWING WORDS...

NOKIA
PANGOLIN
DUOMO
INTRAVENOUS
SYNTHESISER
MANHATTAN
ANTHROPOCENE
TSUNAMI
PINE
TEA
ASTROLABE
MOON
CARWASH
SOCIALMEDIA
SAILING
LEAD
POMPEII
PULSAR
EARTH
TRUSS

Quick-fire questions

Q1 Match the social media sites with the years they launched:

Facebook	2006
Twitter	2010
Instagram	2004

Q2 Anthropocene means 'age of ______'?

- Apes
- Humans
- Ants
- Spiders

Q3 Which physicist was director of Los Alamos during the Manhattan Project in WW2?

A ______

Spot the difference

See if you can find all six changes we've made to the image on the right

What is it?

A...

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9. See if you can beat the team!

	9	3				2		5
6				2	8	9	3	4
		4	9	7	3	8		
9		8		4	5			3
1		7		3	2	4		6
			6	1	9		5	
			3	8	6		4	7
3	8		4	9	7			
	4		2		1	3		9

BEAT THE TEAM...

1  Jackie 02m 55s

2  Charlie 03m 26s

3  Laurie 03m 38s

4  Charlie 05m 32s

5  Duncan 06m 19s

6  James 08m 59s

▶ Visit our website at **www.howitworksdaily.com** to check your answers!

Subscribe and save 20%*

Every issue, delivered straight to your door

Never miss an issue

13 issues a year, and you'll be sure to get every single one

Delivered to your home

Free delivery of every issue, direct to your doorstep

Get the biggest savings

Get your favourite magazine for less by ordering direct

What our readers are saying about us…

"I've been a subscriber to this magazine for a couple of years now and I have never been bored once. The variety every month is just endless and I love that."
Daniel Scott (aged 15) via email

"@HowItWorksmag Best magazine ever!..."
@LeaSavoy via Twitter

"Just started reading @HowitWorksmag about #tech #science & #space. Where have you been my whole life? :) #GeekAndProud"
@DeputyDCooper via Twitter

Pick the subscription that's right for you

MOST FLEXIBLE

Subscribe and save 20%

✔ Automatic renewal – never miss an issue

✔ Pay by Direct Debit

Recurring payment of £26 every six months, saving 20% on the retail price

DIRECT Debit

Instruction to your Bank or Building Society to pay by Direct Debit

Originator's reference 7 6 8 1 9 5

Name of bank

Address of bank

Postcode

Account Name

Sort Code

Account no

Please pay Future Publishing Limited Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with Future Publishing Limited and, if so, details will be passed on electronically to my Bank/Building Society. Banks & Building Societies may not accept Direct Debit instructions for some types of account

Signature

Date

GREAT VALUE

One year subscription

✔ Great offers, available worldwide

✔ One payment, by card or cheque

A simple one-off payment ensures you never miss an issue for one full year. That's 13 issues, direct to your doorstep

UK £51.90 (saving 20% on the retail price)

Europe £78.64 USA £87.08 Rest of the world £96.75

Pay by card or cheque

Pay by Credit or Debit card

Visa Mastercard Amex

Card number

Expiry date

/

Pay by Cheque

I enclose a cheque for £

Made payable to *Future Publishing Ltd*

Signature

Date

Your information

Name

Telephone number

Mobile number

Email address

Please tick if you want to receive any communications from Future and its group companies containing news, special offers and product information.

By post By telephone By email

Please tick if you do not wish to receive any promotional material from other companies By post By telephone

Please tick if you DO wish to receive such information by email

Address

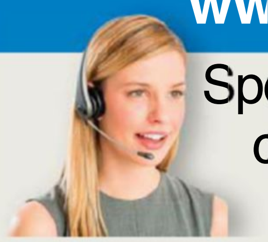
Postcode

Please post this form to

Future Publishing Ltd, 3 Queensbridge, The Lakes, Northampton, NN4 7BF, United Kingdom

Order securely online

www.myfavouritemagazines/HIW/PS17



Speak to one of our friendly customer service team

Call 0344 848 2852

These offers will expire on Saturday 30 September 2017

Please quote code **PS17**

Prices and savings are compared to buying full priced print issues. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magtandc Offer ends 30 September 2017.

HOW TO...
Practical projects to try at home

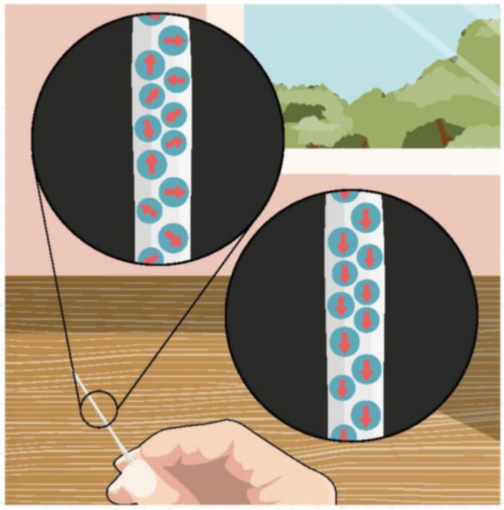
Get in touch
Want to see your ideas on this page? Send them to...

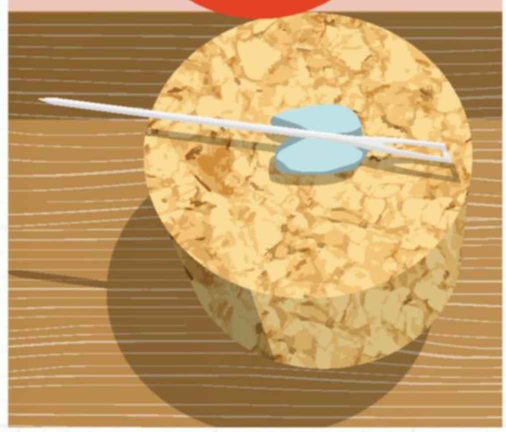
How It Works magazine @HowItWorksmag

howitworks@futurenet.com

Make a simple compass
Use a magnet, a needle and a cork to track north and south

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

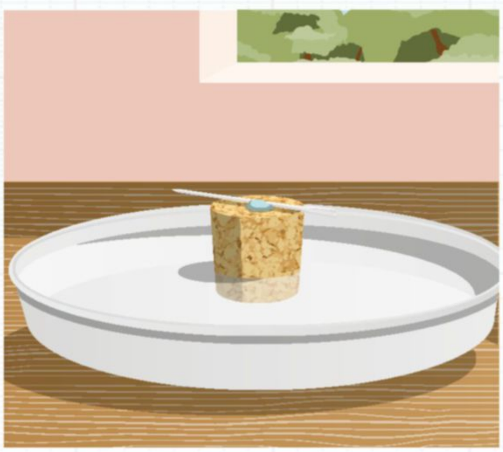


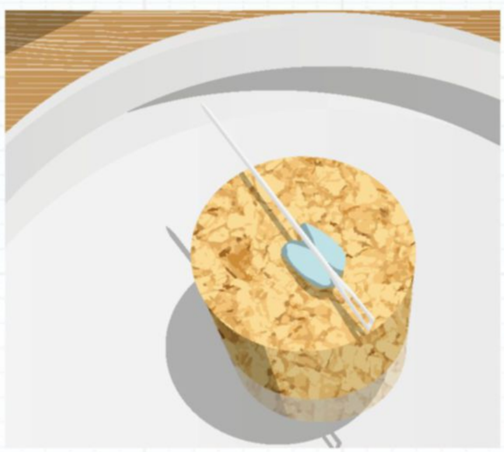


1 Rub the needle
First, you will need to find a bar magnet and a sewing needle. Now hold the needle by the eye – where the hole is – and rub the north end of the bar magnet along the length of the needle. Lift the magnet away from the needle, then move it to the other end and rub it again. You will need to repeat this process 50 times to ensure your needle is correctly charged.

2 Magnetised
By rubbing the magnet along the needle you are moving the charged particles inside the metal, called electrons. Normally they all point in different directions, so the metal of the needle doesn't have a magnetic pull in any particular direction. However, when you rub the magnet along the needle the particles all line up, creating a charge in one direction.

3 Stick it on
In order to create your compass, you need to place your needle in a place that will be able to turn freely, without friction stopping it moving. The easiest way to do this is to place your needle in water – but you need it to float! To make it float, put some sticky tack on the top of a cork and stick the needle into the tack so that it's balanced on the top.





"Rubbing the magnet on the needle makes the particles line up"

4 Get it floating
Run some water into a bowl and let it settle for a few minutes. Any small movements in the water might cause the cork to move, so you want the water to be as calm as possible. When the water is calm, carefully place the cork in the centre of the bowl so that the needle is on top and can move freely. If it starts moving towards the edge of the bowl, stop it with your finger.

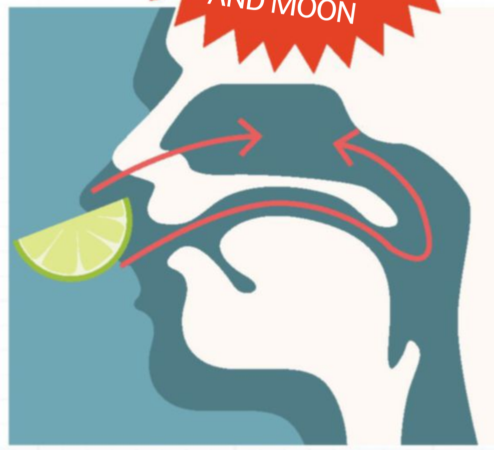
5 North and south
Wait a moment and the cork and needle should start to move – you might have to wait a little while for the needle to settle. The eye of the needle should end up pointing north, while the sharp part of the needle will point south. This works because of the magnetic field created by the metals in the Earth, which affect all kinds of magnetic objects.

In summary...
Magnets create magnetic fields, and these show the pulling power that the magnet has. The Earth's molten metallic core means the planet is like a huge bar magnet, so when you charge a needle like this, it lines up with the magnetic field of the Earth and points north. That's why people can use compasses to navigate!

Test your taste buds

See what your taste buds can do with this simple test!

NEXT ISSUE
TEST FRICTION
CREATE YOUR OWN PLANET AND MOON



1 Chop up some fruit
You might have heard that when you hold your nose you can't taste the things you are eating. To test this out, you can try some strongly flavoured foods while you hold your nose, and then let go to see if you notice a difference in the effects! The best foods to do this with are strong fruits like lemons and limes, but you can also use things like carrots, apples and even sweets. Chop up your fruit to release some of the juices.

2 Hold your nose!
When you taste something, the taste buds on your tongue recognise the chemicals in the food and send signals to your brain that tell you what kind of flavour it has. When you smell things, a similar process takes place in your nose. What's interesting is that the two things are closely linked. Hold your nose and lick the lemon slice – can you taste the lemon's flavour, or do you just get the acidic tingle and no flavours?

3 Release and breathe
Take a big lick of the lemon, and after a couple of seconds release your nose and breathe deeply. You'll find that the flavour of the food quickly floods your taste buds! If you don't get the full effect, or thought you could taste it with your nose pinched, try closing your eyes and asking a friend to touch a piece of fruit to your tongue. Can you tell what kind of flavour it is? Release your nose and find out if you're right!

> "Taste buds recognise chemicals and send signals to your brain"

In summary...
Your sense of taste is quite basic. Your taste buds can only distinguish certain things, such as whether something is sweet or bitter. Specific flavours that would help you tell different fruits apart are sensed inside your nose – so holding your nose stops you tasting these flavours.

© Illustrations by Ed Crooks

WIN!

A pair of Ostara Elinor 10x50 binoculars worth £199.99

Take your nature watching or astronomical observations to the next level with a pair of Ostara Elinor binoculars. This 10x50 model offers 10x magnification with an ultra-wide field of view. The Elinor also contains multicoated lenses for enhanced brightness and clarity, as well as broad lightband transmission for accurate colour.

Which of these is a NASA probe?

a) **Fandango**

b) **Galileo**

c) **Bismillah**

▶ Enter online at **www.howitworksdaily.com** and one lucky reader will win!

INBOX
Speak your mind...

Get in touch
Want to see your letters on this page? Send them to...

How It Works magazine @HowItWorksmag

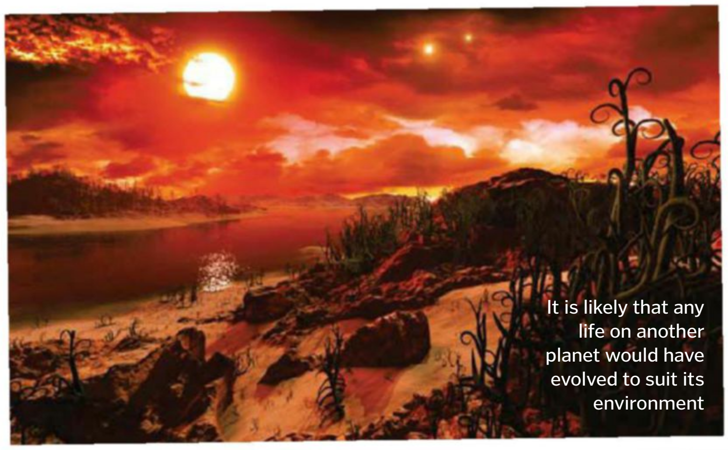
howitworks@futurenet.com

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
30-SECOND MEDICINE
Discover 50 fascinating medical facts in no time with the latest in the 30-Second series

Letter of the Month
What could aliens look like?

Dear **HIW**,
I am an avid reader of your magazines and I am constantly asking my brother if he has finished with it so I can pore over it too. I love reading all of your amazing articles on space as it really interests me. I have a question for you. What is the likelihood of finding extraterrestrial life, and are there any theories on what it would look like? I would really love to have you answer my question please.
Yours sincerely,
Hazel Cooper, age 14

There are lots and lots of theories about what an alien might look like. An alien's morphology would really depend on the type of planet it was living on. An Earth-like planet could be home to aliens that look similar to life here. However, different selection pressures found on distant worlds would cause evolution to take different paths. For example, aliens living on a very dark planet may have evolved to have no eyes and use feelers instead, or a planet with little dry land may have life that is predominantly aquatic and uses gills to breath. Most scientists agree that in a seemingly infinite universe of truly gargantuan size there must be life on other planets, but we can only speculate as to what it may look like.


It is likely that any life on another planet would have evolved to suit its environment

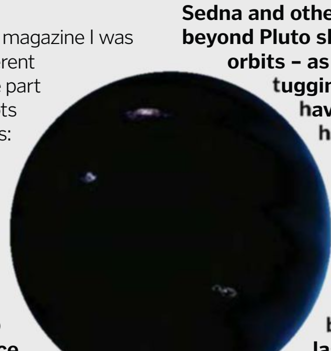
Storage space
Dear **HIW**,
I really enjoy your magazines. Every month I find there's so much I wouldn't know if I hadn't read them. I really enjoyed learning about the funny bone in issue 97. I have a question to ask you. Do we have a minimum amount of space in our brains?
Bert Ramsay, age 12

Scientists don't know if we have a minimum amount of space in our brains, but we believe that there is a maximum amount of space, but it's so huge that we never need to worry about filling it all! We can only make educated guesses because scientists haven't yet figured out how to measure how much of the space is taken up by a memory or a thought. On average, it's estimated that we have about 2.5 petabytes of space in our brains, which is equivalent to the amount of data in 3 million hours of TV shows!


Your brain is so powerful it uses about 20 per cent of your energy intake

Another planet?
Dear **HIW**,
When I first read your magazine I was amazed at all the different sections. My favourite part of issue 99 is the robots feature. My question is: What is Planet X? All I know is it's beyond the Kuiper Belt!
Paul Montague

The hypothetical 'Planet X' (also known as Planet 9) is based on evidence uncovered by Caltech researchers that suggests there may be another unknown planet deep in the Solar System. Though scientists have never actually found it, they are pretty sure it is there because the dwarf planet Sedna and other planetary bodies beyond Pluto share strangely shaped orbits – as if something big is tugging on them - but we haven't located it yet. It has been predicted to be up to ten times more massive than Earth and is so far away that it takes between 10,000-20,000 years to orbit the Sun. There has been a hunt over the last few years to find the planet, so we may find more evidence for it soon.


Planet 9 is believed to orbit the Sun 20-times further away than Neptune

How to become queen bee
Dear **HIW**,
How does a queen bee become different from a normal bee?
Kind regards,
Tobias Hartley

Good question Tobias! The queen bee is selected out from the hive when she is only a larva and exclusively fed the very sweet and nutritious 'royal jelly' through her entire life. It is theorised that this special diet allows her to mature and become fertile. All of the other bees in the hive live on a different diet, and they are not able to sexually reproduce. The queen also secretes a pheromone that suppresses the female worker bees from reproducing.


A queen bee may lay up to 1 million eggs in her lifetime

What's happening on... social media?

We asked our followers what would they create if they could genetically engineer anything...

"For me, I'd love flavored celery. Spicy, sweet, mustard, etc - flavors in such a low calorie package would be amazing."
Amanda Abbott

"Strengthened immune systems in new generations"
Suzie Sasse

"#BioHacking for a more resilient, stronger and smarter human species"
@adu1tg33k1

We were pleased to see that some readers were inspired by our recent Rubik's Cube article!

"@HowItWorksmag inspired by my son's mag, holiday challenge, day 2 I've accomplished it! 30 years behind but never too old to learn. Thanks HIW"
@SarahBreaks

HOW IT WORKS

Future Publishing Limited
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Jackie Snowden**
jacqueline.snowden@futurenet.com
01202 586264
Senior Art Editor **Duncan Crook**
Research Editor **James Horton**
Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Editor in Chief **James Hoare**
Photographer **James Sheppard**

Contributors
Steve Ashby, Alex Cheung, Ed Crooks, Nicholas Forder, Jamie Frier, Tom Lean, Joe Levit, Adrian Mann, Adam Marckiewicz, Laura Mears, Laurie Newman, Jonathan O'Callaghan, Alexander Phoenix, Katy Sheen, Jo Smolaga, Jo Stass, The Art Agency, Steve Wright

Cover images
Thinkstock; Wikimedia Commons; Alamy

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia.
All copyrights and trademarks are recognised and respected.

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Regional Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687368
Media Sales Executive **Jim Henderson**
jim.henderson@futurenet.com
01225 687125

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

Print subscriptions & back issues
Web www.myfavouritemagazines.co.uk
Email contact@myfavouritemagazines.co.uk
Tel 0344 848 2852
International +44 (0) 344 848 2852

Circulation
Circulation Director **Darren Pearce**
01202 586200

Production
Head of Production US & UK **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Controller **Vivienne Calvert**

Management
Finance & Operations Director **Marco Peroni**
Creative Director **Aaron Asadi**
Art & Design Director **Ross Andrews**

Printed by
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed by
Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2041-7322

Future

Future is an award-winning international media group and leading digital business. We reach more than 57 million international consumers a month and create world-class content and advertising solutions for passionate consumers online, on tablet & smartphone and in print.

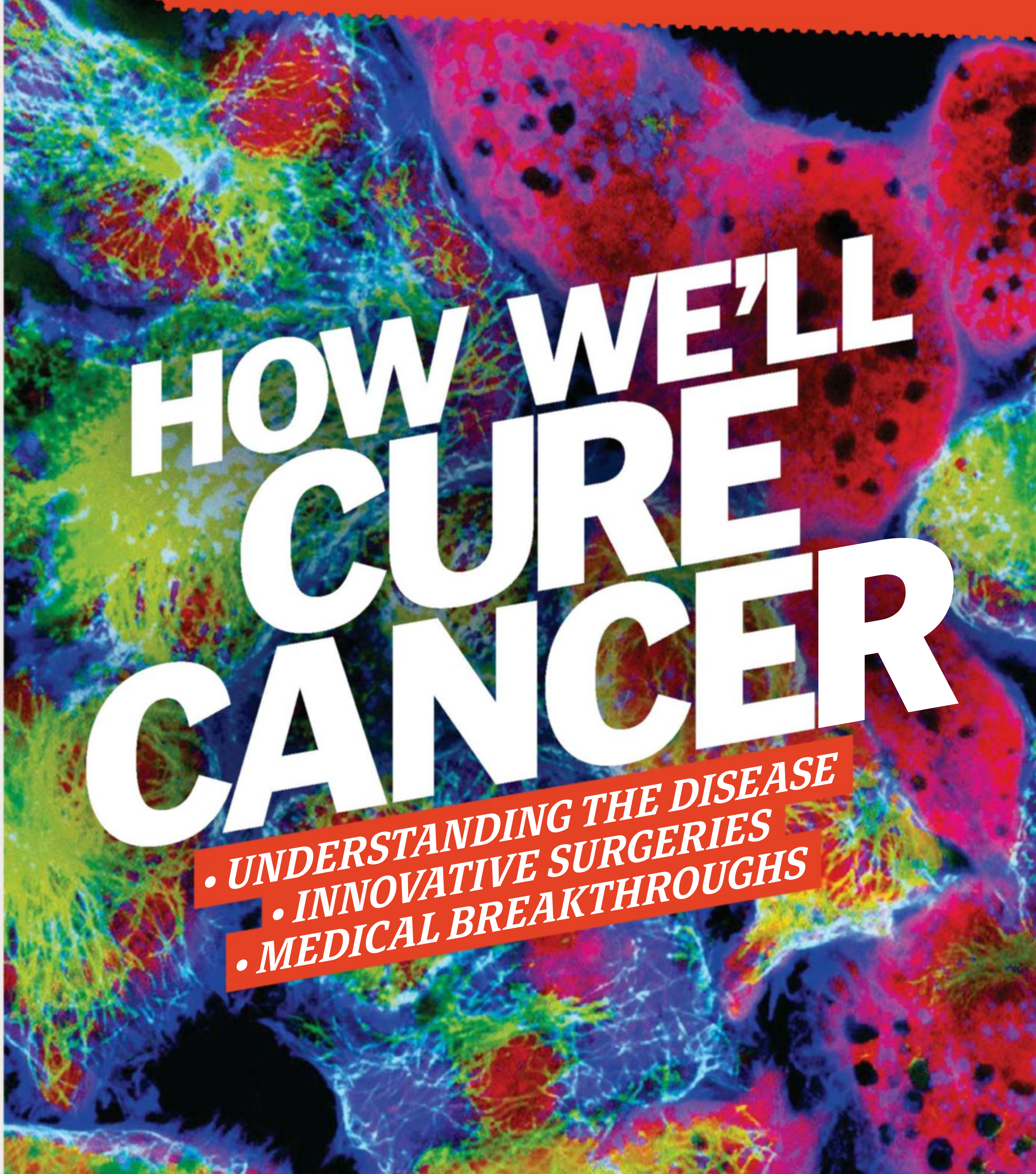
Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR).
www.futureplc.com

Chief executive Zillah Byng-Thorne
Non-executive chairman Peter Allen
Chief financial officer Penny Ladkin-Brand

Tel +44 (0)1225 442 244

NEXT ISSUE

Issue 103 on sale 7 September 2017



HOW WE'LL CURE CANCER

- UNDERSTANDING THE DISEASE
- INNOVATIVE SURGERIES
- MEDICAL BREAKTHROUGHS

Dogs with jobs: meet the clever canines that help us out

How NASA's Space Shuttle program changed exploration

Discover history's greatest heists and robberies

© Thinkstock; NASA

+LEARN ABOUT

■ BODY CLOCK ■ ALCHEMY ■ CRANBERRY BOGS ■ SMART METERS ■ KATHERINE JOHNSON ■ SUPERYACHTS ■ BATTERIES ■ MARS AIRSHIPS

FAST FACTS

Amazing trivia to blow your mind

81.8M
THE HEIGHT OF THE TALLEST PINE TREE

THE EARLIEST EVIDENCE FOR LIFE ON EARTH DATES BACK
3.8 BILLION YEARS

THE SKIN IS THE LARGEST ORGAN OF THE BODY

THE INTERNATIONAL SPACE STATION IS BIGGER THAN A SIX-BEDROOM HOUSE

>2,000
PULSARS HAVE BEEN DISCOVERED SO FAR

800KPH
THE SPEED AT WHICH A TSUNAMI CAN TRAVEL THROUGH OPEN OCEAN

50MN TONS
OF CARGO IS TRANSPORTED BY AIR EVERY YEAR

20%
OF A PANGOLIN'S BODY WEIGHT COMES FROM ITS SCALES

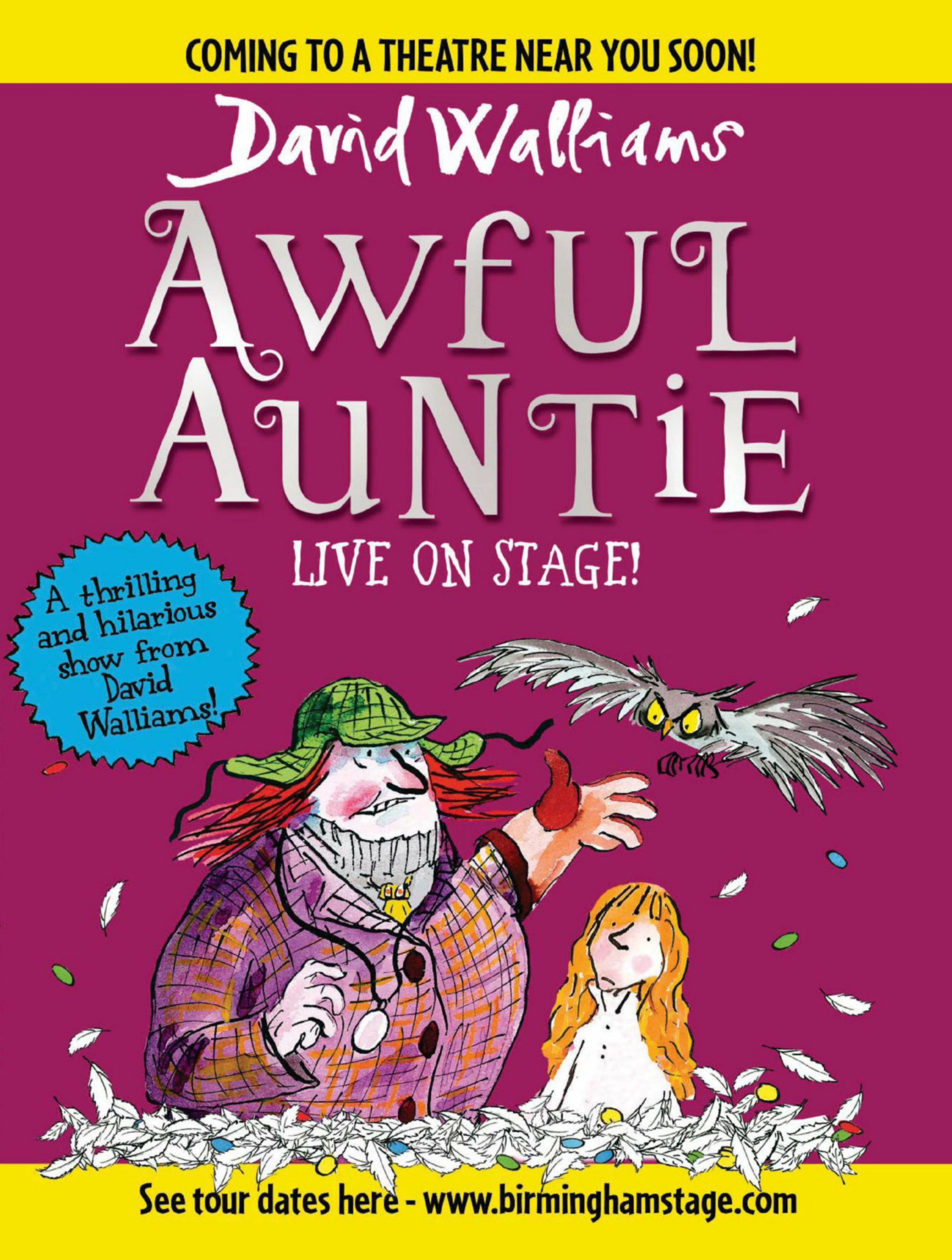
3 MILLION
THE ESTIMATED NUMBER OF SHIPWRECKS IN THE WORLD'S WATERS

34
MUSCLES MOVE THE FINGERS AND THUMB

THE AVERAGE SMARTPHONE CONTAINS MORE COMPUTING POWER THAN THE COMPUTERS THAT WERE USED FOR THE MOON LANDING OF APOLLO 11

69
KNOWN MOONS ORBIT JUPITER

80 MILLION
PHOTOS ARE UPLOADED TO INSTAGRAM EVERY DAY


COMING TO A THEATRE NEAR YOU SOON!
David Walliams
AWFUL AUNTIE
LIVE ON STAGE!
A thrilling and hilarious show from David Walliams!
See tour dates here - www.birminghamstage.com

9012

9000